Statement of Purpose

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I am Bang-Shien Chen, a graduate student from the Department of Mathematics, National Taiwan Normal University. My research interests are in ***Optimization*** and ***Robotics***.

Past research: Machine Learning & Quantum Computing

As a student of Mathematics, I have developed a solid foundation in theoretical concepts and analytical techniques. While these skills sharpened my ability to think abstractly and solve complex problems, my growing interest lies in applying these principles to real-world problems. To achieve this goal, I have self-learned machine learning and programming techniques through online courses. In my senior year, I worked on several projects with Prof. Jann-Long Chern related to machine learning and quantum computing.

Recommendation system

My first project involved developing a neural network-based movie recommendation system with feature analysis, which earned a presentation award at the Taiwan-Japan Joint Workshop for Young Scholars in Applied Mathematics. Through this project, I gained valuable experience working with ***neural network models*** and ***machine learning toolboxes***.

Quantum computing

Following this, I attend a workshop on quantum machine learning. This experience led me and Prof. Chern begin studying quantum mechanics and quantum computations. Quantum computing has attracted lots of attention due to promising quantum algorithms, where quantum machine learning could improve computational speed and reduce data storage with the benefit of quantum properties. I undertook a project on auto-generating quantum feature maps for Support Vector Machine [1], exploring high-dimensional quantum space.

In addition, I participated in the IBM Qiskit Hackathon Taiwan 2022 and won the first prize for solving large combinatorial optimization problems. Our team proposed to decompose large problems by separating them into smaller systems, applying matrix decomposition in the Hilbert space. This significantly reduced the computation time while preserving comparable performance levels.

Our next project focused on encoding arbitrary matrices onto quantum circuits [2]. While there are some promising quantum algorithms that has lower time complexity, implementing quantum circuits are usually associated with high gate-cost. To address this, we developed an efficient way to encode matrices while minimizing the number of quantum gates, utilizing group representation theory and matrix computation. Throughout these projects, I gained a solid understanding of quantum mechanics, and learned how to ***leverage my mathematical background to solve problems*** efficiently.

Current research: Optimization and Robotics

I am currently a 2$^{\text{nd}}$ year master student under the supervision of Prof. Jann-Long Chern and Prof. Chih-Wei Huang. With Prof. Huang's expertise in robotics localization problems, my research has increasingly focused on challenges in the fields of robotics and computer vision.

Visual Odometry

During the 1$^{\text{st}}$ year of my master, Prof. Huang collaborated with ASUS on an industrial project aimed at developing a vision-based odometry model. Given that neural network-based models generally exhibit superior performance, we incorporated state-of-the-art techniques, including transformer

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models and uncertainty models. While the model's performance was excellent, my supervisors frequently posed the question: *Is there a mathematical model that can quantify how great our solution is?* During my research, I discovered a research direction that greatly interested me: ***certifiable algorithms*** [4, 5, 6]. The central concept behind certifiable algorithms is to utilize optimization techniques along with optimal conditions, allowing us to study the optimality of a models solution. This leads to my the core idea of my recent work, FracGM [3].

Optimization & Spatial Perception

FracGM is a Geman-McClure robust estimator that leverages fractional programming techniques. It is designed from a fundamentally different perspective compared with existing state-of-the-art methods, achieving not only better performance and faster convergence, but also inheriting the theoretical advantages of fractional programming, including ***studies on global optimality***. We demonstrate FracGM on spatial perception problems, outperforming state-of-the-art solvers, and also provide examples showcasing FracGM is a global solver.

By the end of the 1st year of master study, I was awarded a ***research abroad program*** financially supported by the Mathematics Division of National Center of Theoretical Sciences, Taiwan. I spent three months working with Prof. Shuzhong Zhang, a renowned expert in optimization, at the University of Minnesota. After introducing my previous work to him, we immediately came up with new algorithms. We further simplified the fractional formulation to a quadratic program, which enhanced computational efficiency while maintaining performance comparable to FracGM. In addition, I visited Prof. Volkan Isler at the Robotics Institute and shared my work with him and his team members. The experience also deepened my interest in pursuing a Ph.D. program in the States, given the vibrant research environment and opportunities for collaboration.

Future research: Certifiable Algorithms

Robotics and automation have become crucial technologies in recent years, enhancing efficiency, productivity, and precision by automating human tasks. However, for more complex tasks such as self-driving cars, ensuring safety and trustworthiness remains a critical challenge. While various researches about autonomous systems demonstrate impressive performance, validating performance guarantees can often be difficult. For example, neural network-based models generally offer great performance, but *can we truly trust a neural network-based self-driving car in real-world scenarios?* My research objective is to develop ***certifiable algorithms based on optimization techniques***, leveraging optimal conditions to obtain performance guarantees, ***to trust the solution***.

I have rich domain knowledge in Robotics and Optimization, and I look forward to opportunities that may benefit my research goal: ***applying optimization techniques to solve real-world problems along with solution optimal guarantees***. Thank you for your attention to my statement of purpose.

References

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