Statement of Purpose

My primary research objectives and interests span AI, robotics, and mechanical engineering. I am currently engaged in research at Safe AI Lab, Carnegie Mellon University, and I am actively involved in a research project that is developing a generalizable skill-based imitation learning policy for robot arm manipulation in dynamic environments. My work focuses in particular on data-driven approaches for sample-efficient training and bridging the sim-to-real gap of deploying learning-based robot control in the physical world. This project has opened my eyes to a broad range of research in robotics and motivated me to undertake further study through a Ph.D. program. I am especially interested in the research of robust intelligent robot control generalizing to multiple tasks and scenarios, but I am open to trying new ideas as well.

The extensive involvement with robotics in my undergraduate and master's programs has shaped me into a mature engineer. I am skilled in various domains such as design, force/dynamic analysis, robotics, control, and programming. In my undergraduate thesis: Optimization of Hemispheric Resonator Gyroscope under the guidance of Prof. Xuefang Wang, I established the mathematical relationship between the dimension of the resonator and first twelve-order resonance frequencies through finite element analysis and function approximation. A challenge was encountered that the extremely thin shell of the resonator was hard to model and build meshes on. I solved the problem by scaling up the model, conducting test on the enlarged model, and building another relationship between model size and resonance frequencies. This method was validated in physical tests, demonstrating accurate trends in resonance frequency variations with changes in dimension and shape. The contribution of this work is the simplification of modeling the resonator's resonance frequency, circumventing complex calculations in material mechanics and vibration theory, and proved particularly beneficial for designing resonators with intricate shapes.

My problem-solving and critical thinking abilities have been sharpened through various robotics projects. During the team project on tumbler robot control, I pinpointed the issue lying in one motor outputting insufficient force, impacting our control effectiveness in extreme cases. Given the success of our LQG controller in Simulink in maintaining our robot standing upright even with large interruptions, I discussed with teammates and determined there must be a sim-to-real gap in either sensor output or actuator performance. After ruling out other factors, I detected a subtle variance in the sound of the motors, leading to the discovery of a performance difference between them.

Although I have dedicated considerable effort to the field of robotics, I have been actively absorbing knowledge from additional areas, with machine learning particularly intriguing me. Towards the end of 2022, I started to recognize the growing significance of machine learning in robotic planning and decision-making. Its potential to foster more intelligent robots for enhancing human welfare captured my interest. In the final semester of my master's program, I proactively expanded my knowledge by taking relevant courses. As I delved deeper, I was fascinated by the flexibility of neural networks as function approximators and their potential to achieve optimal control strategies, some of which may extend beyond our current understanding, when trained using reinforcement learning algorithms.

Continuing my journey, I have ventured into research with machine learning further evolved. After graduation, I decided to join Safe AI Lab, under the guidance of Prof. Ding Zhao, in the mechanical engineering department to deepen my knowledge in AI and robotics. My current research project, aimed at contributing to the Robotics Science and System conference, focuses on generalizable decision-making in robot manipulation. In this project, I collected expert data in robosuite simulator with rule-based controllers and planners, aiming to train models with data-efficient offline learning approaches. I designed a skill-based imitation learning policy with task-specific skills encoded by Gated Recurrent Unit network and inferred from energy-based models. With prior knowledge from the data, the agent is capable of achieving commendable performance with just a single multi-layer perceptron. This method demonstrates a high success rate and generalizes to randomly initialized task scenarios. My work has also been deployed to real-world robot arms such as Kinova Gen3 and Ufactory xArm7, aiming to make learning-based robot control more accessible to people.

During my research projects, my diverse experience in control systems and mechanical engineering has proven to be a unique strength in my research. I've discovered that my background in control systems significantly enhances my research in data-driven offline learning methods, where I could effectively leverage controllers like MPC and planners like A* and RRT as an expert for data collection, or as a baseline in my research. Additionally, my expertise in mechanical design proves invaluable in projects that integrate morphological considerations with learning algorithms.

My research experience further reinforced my conviction in the synergy of robotics with AI, particularly in materializing intelligent robots in the real world. This passion fuels my ambition to expand my knowledge and skills by pursuing a PhD in the area of robotics. Additionally, I enjoy exchanging ideas in this field, which has spurred my interest in exploring the opportunity to serve as a teaching assistant during my doctoral program. Through my graduate studies, I expect to become, and will work hard to be, an effective researcher.

For these reasons, the robotics research at the Mechanical Engineering Department of Stanford University is especially attractive to me. I am intrigued by several interesting research projects carried on by their faculty members. Specifically, Prof. Monroe Kennedy III's work in assistive robotics is particularly compelling, with their paper “It Takes Two: Learning to Plan for Human-Robot Cooperative Carrying” being particularly inspiring. Furthermore, Prof. Chris Gerdes's research in automotive robotics aligns closely with my academic aspirations. His paper “Learning Policies for Automated Racing Using Vehicle Model Gradients” is an engaging and relevant read for me.

Through my extensive background and diverse experiences, I am confident in my suitability as a strong candidate for the PhD. I am eager to discuss my qualifications with you at your convenience. Thank you very much for your time and consideration of my application.

Sincerely,

Yiqi Lyu