Statement of Purpose

My research ambitions center on developing intelligent robot systems by integrating mechanical engineering, control theory, and artificial intelligence. I am currently engaged in research, advised by Prof. Ding Zhao, at Carnegie Mellon University, which involves developing a generalizable robot arm manipulation system in dynamic environments. My work there focuses on training robot decision-making policy via data-driven approaches and real-world deployment of intelligent robot systems. This project has strengthened my passion for robotics and motivated me to pursue advanced study through a Ph.D. program. During my doctoral study, I hope to explore the integration of control and learning, aiming to forge safe, intelligent robot control with adaptation to diverse tasks and scenarios, but I am open to trying new ideas as well.

My doctoral study will uniquely benefit from my interdisciplinary background cultivated since my undergraduate studies. 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. A challenge was encountered that the extremely thin shell of the resonator was hard to model and build meshes on. I innovatively solved this problem by scaling up the model, conducting tests on the enlarged model, and estimating the original model's attributes based on the test data by building another relationship between model size and resonance frequencies via function approximation. 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 skills have been further sharpened through various hands-on projects during my master's studies. For example, in a 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 controller in Simulink in maintaining our robot standing upright even with extensive interruptions, I discussed solutions with my 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.

Though considerable effort has been dedicated to the field of robotics, control, and mechanical engineering, I have been actively seeking knowledge from additional areas, especially machine learning. After graduation, I was hired by Safe AI Lab at Carnegie Mellon University where I deepened my knowledge in robotics and AI. My current research project, which my mentor and I hope to present at the Robotics Science and System Conference 2024, focuses on generalizable decision-making in robot manipulation. In this project, I collected expert data in the robosuite simulator with rule-based controllers and planners, aiming to train models with sample-efficient offline approaches. I designed a skill-based imitation learning policy with task-specific skills encoded by Gated Recurrent Unit networks 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 has further reinforced my belief in the synergy of control and AI, particularly in materializing intelligent robots in the real world. Despite the progress in learning-based robot control, the path to their commercialization remains challenging, particularly in ensuring robustness, safety, and generalizability. I believe the integration of control theory, providing a safety framework, with learning approaches, offering intelligent decision-making capabilities, is the key to overcoming these challenges and propelling the field forward. This conviction fuels my ambition to expand my knowledge and skills by pursuing a Ph.D. My interdisciplinary expertise will help me to further my academic success and to be a prominent researcher, making significant contributions to the evolution of trustworthy, intelligent robotic systems.

Through my extensive background and diverse experiences, I stand confident and enthusiastic about embarking on doctoral studies. I firmly believe that these qualities, coupled with my unwavering dedication, will support my success in the Ph.D. program at Mechanical Engineering Department.