Research Statement

My name is Zhixiong Wang, and I will graduate from the Hangzhou University of Electronic Science and Technology. During undergraduate studies, I actively participated in an Internet of Things(IoT) competition and completed my graduation project, titled "Design of an IoT-Based Smart Clothes Drying Rack."; This previous research has laid a strong foundation for subsequent studies, enabling me to adapt more swiftly to further research endeavors. During graduate studies, I collaborated with a senior colleague on path planning, where we employed the BAS (Beetle Antennae Search) algorithm in conjunction with A* to optimize local path planning, and achieved global optimization and robustness by emulating the biological behaviors of cuckoos and beetle swarms. We further validated the algorithm using both simulation software (RVIZ, Gazebo) and physical robots, resulting in a published paper. Additionally, I combined the ZNN(Zeroing Neural Network) and the error state of MSCKF algorithms, which resulted in an exponentially converging output trajectory error, thus improving the trajectory precision of the system. This improvement was validated ROS and physical robot cars, with a paper currently under review. **These projects contributes to my subsequent experimentation in MushroomRL environments and on the TIAGo++ robot. This project further honed my C/C++ programming and debugging skills, providing valuable assistance for following safety projects.** Presently, my research focus revolves around the integration of deep learning with SLAM, which retains static feature points within YOLO bounding boxes, reducing the interference in robot localization caused by dynamic points, which results in an increase in trajectory and positioning accuracy. In this project, I acquired proficiency in Python and PyTorch, which has substantial implications for the integration of reinforcement learning and robotic security systems in subsequent work.

Robotic systems are becoming increasingly prevalent in our daily lives, from manufacturing and logistics to healthcare and personal assistance. However, the deployment of robots in real-world scenarios poses significant safety challenges. Any control policy should avoid dangerous actions that could harm the environment, humans, or the robot itself. I've noticed that your laboratory has conducted extensive research in this area and has produced a lot of outstanding work[1][2].

I am particularly interested in robot control and safety direction, and I have read Dr. Davide Tateo's paper[1]. This research is very meaningful and can continue to **explore the connection of the fields of reinforcement learning and control theory,** the use of more complex constraints, or combining vision to learn complex high-dimensional tasks in dynamic, unstructured environments while ensuring safety, as well as exploring the use of this approach in real-world scenarios with physical robots.

To achieve these objectives, **I plan to implement** an observer-based adaptive backstepping decentralized controller[3] into this robot security system. Adaptive control methods allow the controller's parameters to be adjusted in an adaptive manner, considering the system's dynamic characteristics and the influence of external disturbances. In the context of the safety problem in RL, to maximize the discounted cumulative reward: $max\ E_{\tau\sim\pi}[\sum_t^T \gamma^t r(s_t, a_t)]$, the original system estimates the state variable S_t. Through the use of a radial basis function neural network, the controller can adaptively modify the reward function r_*, ensuring stability and safety within the controller even in the presence of irregular disturbances in Brownian motion. The

observer-based adaptive backstepping decentralized controller guaranteed the signals in the closed-loop system were semi-globally uniformly and ultimately bounded in the fourth moment. This feature is of utmost importance for the safety and robustness of robotic systems. I have prior experience with C/C++ programming and debugging, which will aid me in completing this step. **For experimental design**, I will first apply this approach in MushroomRL environments under various challenging conditions, such as situations with obstructions or the need to avoid collisions with multiple dynamic objects while accomplishing static target-reaching tasks. I have previous experience conducting two experiments in virtual environments, which will assist me in successfully completing this experiment. Additionally, I will design more complex tasks in the field of Human-Computer Interaction (HCI). These tasks will involve interactions with a real robot, the TIAGo++ robot, where a human attempts to ignore the robot that tries to deliver a cup of water and take other items from the table safely, meanwhile, place an obstacle at the foothold when the cup is about to fall. I also have prior experience conducting experiments with physical robots. My prior research and skills are well-suited for the successful completion of this project, and I am eager to actively engage in and contribute to the research efforts within your laboratory.

As for comparative experiments, I will record the data on discounted reward, the final distance reached across evaluations, the number of early terminations due to damage events, the average steps per episode, the total number of episodes and average episode steps. These data will be used for experimental comparisons with methods such as ATACOM, vanilla SAC, SafeLayer, and a hard-coded Linear Attractor (LA). I have prior experience in data collection and data processing using Python, which gives me the confidence to successfully accomplish this step.

I want to work in the PEARL group of Prof. Georgia Chalvatzaki because I find that my research plan aligns closely with the research focus of your group, and I believe I can acquire a wealth of knowledge within your research group. Your lab has very strong research resources, for example, MushroomRL , TIAGo + + and other hardware are critical to my research plan. In addition, I was also inspired by many outstanding studies in the laboratory. Your group's research direction is in line with my aspirations for my scientific career, and I am eager to delve deeper into this field. I really hope to work in this traditional research environment.

I believe my research will hold significant importance in the field of robot safety. I have a strong desire to publish articles in high-quality conferences and journals like ICRA, IROS, or RAL. I have some relevant skills and knowledge, and I have great confidence that I can complete these tasks in the years of my PhD.

[1] Liu P, Zhang K, Tateo D, et al. “Safe reinforcement learning of dynamic high-dimensional robotic tasks: navigation, manipulation, interaction,” in 2023 IEEE International Conference on Robotics and Automation (ICRA). IEEE, 2023: 9449-9456.

[2] Liu P, Zhang K, Tateo D, et al. Regularized deep signed distance fields for reactive motion generation[C] 2022 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS). IEEE, 2022: 6673-6680.

[3] Wang H, Liu P X, Bao J, et al. Adaptive neural output-feedback decentralized control for large-scale nonlinear systems with stochastic disturbances[J]. IEEE transactions on neural networks and learning systems, 2019, 31(3): 972-983.