Duo Zhang — Personal Statement for Rutgers University

Growing up in a small town where the people there provide a major proportion of coal and electricity to the whole range of China, we are famous as "The City of Coal". My grandpa, my father, and all my uncles have been working at various power stations scattered in my hometown. I have seen workers who are suffering from respiratory diseases, and heard workers died of accidents in the tunnels of coal mines. My beloved grandpa also got lung cancer and finally passed away because of it. Emerging from the fiction I had read, I began to wish I could bring all kinds of robots to real life and make them do hazardous jobs for the workers, contain the pollution and take care of my family. Since then, this envision became the dream of my life and I want to help the people who are bedeviled in the severe working environment. Luckily enough, I stepped into the world of Computer Science and Robotics and have done a few projects that will capacitate the robot to have some level of intelligence to interact with people, plan a gesture or trajectory, or manipulate random objects without being hard coded by human beings. Although the achievements I had now are far from my dream, I strongly believe this is the correct way to go and this is why I want to pursue a PhD degree to explore the possibilities in robot intelligence.

The Way To Robotics. Focusing on robot intelligence, I started my first project with Prof. Changhe Tu in my senior year at Interdisciplinary Research Center, Shandong University. Our lab collected abundant data on hand gestures and trajectories with a VR set while human beings tried to reach and manipulate various objects. With the data, I developed a model with VAE+LSGAN to generate trajectories that are most legible and understandable to human beings for the end effector on a robot arm. The model can be utilized in different scenarios (e.g. A worker can easily understand where the robot is trying to reach in a handover task), and I finished my undergraduate thesis with this project.

After graduation, I stayed in Prof. Changhe Tu's lab as a research assistant. This time I targeted a constant hot spot in robotics, the grasping planning problem with Dr. Zherong Pan and Dr. Xifeng Gao. We found that some of the existing work relies on sampling contact points from the gripper and the target object, which greatly limits the possibilities of gripper gestures and because of the sampling method, the generated gripper gesture could have penetrations with the target object especially when the object is very thin. In the exploring process, I learnt how to identify the flaws in previous work, and define the scope of our research problem. Besides, I participated in developing our algorithm which discards the sampling method and allows contact to happen between any pair of points on the gripper and the object. In other words, we extended the model-based planning methods of precision grasps to power grasps. In the meantime, our method is guaranteed to be strictly penetration-free. This project finally led to my first paper *Planning of Power Grasps Using Infinite Program Under Complementary Constraints* submitted to RA-L 2021. Although I enjoyed every moment during this project, there's still a question haunting my mind-"Only a grasp planner is not enough for the workers at the coal mine or power station, how can I give more ability to robots in a more complicated work environment or facing with more complicated objects?"

My next project, *Teach the robot how to handle deformable objects* helped me to answer part of the question. After I joined NYU, I started to work with Prof. Daniele Panozzo and Prof. Lerrel Pinto. I noticed my first paper can only handle rigid objects and the final gesture generated by our algorithm heavily depends on the geometric shape of the target object. Thus there's no guarantee that our algorithm will still work on deformable objects. So our project aimed to enable the robot to manipulate deformable objects on certain tasks using the policy

transferred from what the robot has learnt in the simulation. This is my first time managing such a giant project with efforts at both software and hardware level. I developed a series of openAI gym environments that integrated the PolyFEM simulator to support reinforcement learning dealing with deformable objects. Besides coding, I set up a group of cameras to track the target objects and I also validated the feasibility of experiments we proposed on the real robot such as making the robot shoot a silicone rubber ball with a slingshot. This project is still ongoing and it will take very long time to complete it, but my confidence to get some results from handling deformable objects has never been strengthened and consolidated as it is now.

With the desire to answer the whole question of mine, I joined the research group of Light-Speed & Quantum Studio of Tencent as an intern this summer to continue working with Dr. Zherong Pan to solve the trajectory planning problem that would help robots to find a trajectory that is absolutely safe from the starting point to the destination. We found that most existing work needs to sample time instances from the whole time period while the robot is moving to check if there are unsafe collisions. However, this approach has no safety guarantee on any other time instances other than the sampled ones. Our main contributions are that we mathematically found a temporal motion bound that conservatively estimates the range of motion of a point on the robot over a finite time interval and a motion subdivision scheme that recursively reduces the error of conservative motion estimation. We also developed a solver that with the motion bounds, we can search for trajectories that have zero collision at any time instances. This project led to my first paper as the first author *Provably Robust Semi-Infinite Program Under Collision Constraints via Subdivision*. This paper is still on arXiv and we plan to submit it to RSS 2023.

Retrospecting on all my projects on robotics, I found myself having never been this close to my dream at this moment. After reading the works of Prof. Jingjin Yu at Rutgers University with great excitement, I was intrigued by his research on Motion Planning and Robot Manipulation, and I reckon my projects on grasp planning and trajectory generation align well with Prof. Jingjin Yu's work. I realized this is the perfect chance for me to extend the range of my knowledge and skills at Rutgers University and to learn how to really help people by putting real robots in people's lives instead of staying at the level of theories.

Myself and Future Plans As a first-generation graduate student from a family rooted in coal mines and power stations, I spent two years in college learning Energy and Power Engineering as an undergraduate and tried to follow the path of my family. I thought I could make a difference in my hometown by becoming an expert in power stations, but I found I was wrong. To change the situation, I need more effort from other aspects that are outside of a power station. That's why I changed my major to computer science and resorted to robotics for solutions. I extremely cherish the chance to have such a high-level education. After my PhD career, I thirst for continuing my journey in academia. I am passionate about putting my research to the place where people really need them to improve their living standards. I have been a volunteer worker at different nursing homes, and I have also been a volunteer teacher at a local elementary school in my hometown. Maybe what I can do is very limited, but the joy and comfort after helping others is unlimited. With my expertise, I would dedicate the rest of my life to doing something for the greater good.