Letter of Motivation: Pengzhi Yang

In the TV series, *Love, Death, and Robots*, **Zima**, a great artist, traces his genealogy back to his origin, uncovering his evolution from a hard-coded underwater robot. I have always possessed a deep fascination for intelligent robots, anticipating their revolutionary effects on society. Thus, this utopian sci-fi story, depicting a future wherein robots had attained consciousness, inspired my thoughts on how smart robots will interact with the world beyond assisting humans with repetitive tasks. To delve deeper into this field, I have been committed to improving my computer science skills and conducting research on robotics using AI technologies – with a specific focus on deep reinforcement learning (DRL).

Driven by curiosity, I joined Tencent RoboticsX Lab as a machine learning intern. The lab built quadruped robots capable of walking on a few specific surfaces. Nevertheless, to deploy them in capricious real-world applications, a versatile manually-designed controller would be indispensable, which involves complicated development processes, substantial background knowledge, and plentiful experience. Comparatively, DRL-based controllers, trained based on abundant simulation data, are becoming competent alternatives. However, the lack of robustness and difficulty in transferring the trained models from simulators to the real world due to *sim-to-real* gaps would influence the system's performance. Afterward, I focused on resolving the first problem on an algorithmic level. Firstly, by randomizing the robot dynamic settings (friction, inertia, etc.) at each training episode in the simulator, the collected training data variety was significantly enriched. Secondly, I proposed and implemented a *Domain Adaptation* approach: the robot perceives the dynamics during locomotion with one identification network and applied the estimated dynamics parameters to adapt its policies in various environments with a policy network. Through utilizing the proposed method, the quadruped robot ultimately achieved promising performance at last in real-world challenges.

The internship experience and immense challenges inspired me to continue independent robotics and AI research. Therefore, I participated in an underwater robot end-to-end navigation project at Dartmouth College. Compared to ground and aerial robots, Autonomous Underwater Vehicles (AUV) applications exhibit severer underlying difficulties, including higher requirements for controlling the robot, more irregular and non-static underwater environments as well as fewer choices for low-cost or precise perception configurations. Most importantly, the sophisticated underwater scenes influenced by attenuation, scattering effects, and worse light conditions prevented us from directly employing existing laser-based obstacle avoidance methods for ground robots.

To tackle the problems, I combined a monocular camera with a single-beam echosounder to exploit both of their strength for navigation: having a relatively wider field of view with accurate distance information from sonar. However, the RGB images captured by the camera lack producible information which introduced environmental understanding problems for the perception. To remedy this, we incorporated the *vision transformer* as a backbone feature extractor to obtain useful pixel-wise relative distances to front obstacles. The predicted depth information stacked with sonar readings and goal positions is then fed into the policy network to control the robot approaching the target positions. Nevertheless, depth estimations still are influenced by water conditions which affect the overall navigation performance. We then applied Unity for realistic underwater scenes, and leveraged *Domain Randomization* technique by randomizing the scenes' visibility during training. Finally, the trained model was proven to be more robust to underwater environment variations. During field experiments, the autonomous swimming robot reminded me of the wise robot artist, **Zima**. Their serendipitous association further strengthened my aspiration to engage in the future creation of more intelligent robots.

In this eye-opening research project, we formulated a POMDP problem using sequential observations as the perception model. However, I wondered how to restrict these kinds of trajectory planning tasks within an MDP formulation. Inspired by this notion, I joined the Existential Robotics Lab at UC San Diego and worked on target-tracking projects. I explored how to get the agent to move efficiently to track the moving targets under uncertainties by maximizing the information gain. Making use of *Kalman filter*, the mean and covariance matrices for target position information are maintained and fed into the attention-based policy network. With the information covariance matrix, the uncertainty is known by the model. Under this setting, previous timesteps' observations are not requested for path planning while the task is also transformed into an MDP problem. This project enriches my background in control and also exposed me to the fantastic prospect that AI is playing an increasingly critical role in robotics field.

The highly interdisciplinary nature of robotics demands its practitioners possess broad intellectual dimensions and a comprehensive understanding of the domain. But among the subareas, the most exciting topic for me has always been exploring robot intelligence with AI algorithms. As one of the world's strongest universities, ETH is at the forefront of Robotics, AI, and Computer Science, and this summer research program provides invaluable opportunities. I am particularly fascinated by the ongoing research projects at Prof. Robert Katzschmann's Soft Robotics Lab, which focus on developing soft robotic systems. Moreover, their research encompasses developing multiphysics simulations leveraging physics-informed neural networks, to facilitate computational design of soft body control. I believe these projects will have a profound impact on the field of intelligent robotics by enabling more efficient human-robot interactions. In addition, I'm also deeply intrigued by the research initiatives at Emilio Frazzoli's Lab and Autonomous Systems Lab on developing autonomous systems such as self-driving, quadruped robot locomotion, and decision-makings for longer drone flights based on multi-modal perceptions.

I genuinely hope to be granted the opportunity to join the excellent academic community at ETH and would continue my research journey in intelligent robotics after this program. I'm confident that I will be a qualified candidate, and I am looking forward to contributing to robotics research with my strength, insights, and passion. Thank you for your thoughtful consideration of my candidacy.