Research Statement of Chao NI

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I obtained my master's degree in Robotics at ETH Zurich, where I broadly researched learning-based robot locomotion and exploration planning. My master thesis aimed to leverage optimality from the model-based approach to the network-based controller and achieve smooth sim-to-real transfer. I also actively researched exploration planning and proposed a framework to learn the sampling distribution from next-best-view samples and bias the exploration towards the frequently visited area. Both works are turning into publications and have addressed different aspects of robot autonomy: sensing and motor. These, together with my short stay as a SLAM engineer for a driverless car organization, motivate me to create a tight integration between perception and control. Towards that end, I joined Prof. Amir Zamir's group at EPFL as a graduate research intern and I am currently working on investigating the relationship between visual capacity and downstream action tasks. I believe that with a better understanding of how perception is utilized and processed for different tasks, I will be a step closer to my future goal of developing an inseparable, yet interpretable training paradigm for robotics.

Graduate Research

During my studies at ETH Zurich, my research mainly focused on the learning-based autonomy of mobile robots, including perceptive control, planning, and trajectory optimization. In my thesis (Ni, 2021), I used imitation learning to leverage knowledge from the Model Predictive Control (MPC) expert to the network-based controller under structured terrain. This enables the robot to be aware of the obstacles and move accordingly. Our work leaves the network training purely in simulation with data collected from a reliable MPC expert and achieved sim-to-real transfer. Additionally, the trained policy behaves like a model-based expert but can be inferred at a low computational cost.

I am also interested in the planning of the robot where the robot has to either explore the environment or reconstruct the map with limited battery power. In another work (Schmid et al., 2021) with Prof. Roland Siegwart, I developed the framework for sampling exploration points from a learned distribution in an unknown environment. We used conditional variational auto-encoder (CVAE) to learn the latent representation of best samples generated from a uniform planner. Our framework can achieve faster exploration and opens up possibilities for more complex real-world applications such as inspection and rescue.

Current Research

However, a fully autonomous robot requires a long-range sight and long-term memory. I use LiDAR perception to solve the problem of *how* to move under structured terrain for a legged robot in my thesis, but it requires a human to give the twist command. My other work, on the other hand, focuses on *where* to move based on the local map. However, this involves an abstract occupancy map and local planning. Thus, further research on a more realistic perception input and global reconstruction remains to be explored. With the idea of bringing memory-rich and realistic perception to the movement of the robot, I joined Amir Zamir's group at EPFL, where I am working on the relation between visual capacity and the action task. In the robotics area, perception input is often task-specific and requires humans to design features for downstream tasks. Current methods of selecting and processing perception features in a general and interpretable way do not exist. We believe this can be implicitly done by relating the visual capacity to the downstream action task, e.g. segmentation to navigation. This will free us from the burden of training from pixels and provide a better understanding of the roles of visual capacity in an autonomous task.

Future Research Goal

My research goal is to create a tight integration between perception and control. Current approaches tend to decouple these two and treat them in isolation. However, this is not always the case for a more intelligent robot. A cheetah will adjust its moving direction and its gait based on the same perception towards its prey, this (long-term) perception input explains not only its seeking strategy (*planning*) but also how it drives its muscles (*control*). To achieve this goal, one needs to think over the general pipeline of how an autonomous robot acts given the perception input. Also one needs to be not confined to the current decoupled fashion and to adopt more interpretable components in the training procedure. Last but not least, a prerequisite in a good understanding of computer vision and robotics, as well as a strong background in implementations, are needed. I had the privilege to work with experts in these fields, from whom I gained much insight and knowledge. I have also mastered the necessary programming skills, such as C++ and Python.

Conclusion

I believe that a more integrated combination in the vision-action loop will be the future of robotics. The potential of robotics proliferates given the rapid development in computer vision and reinforcement learning algorithms. My experience in robotics control, exploration planning, and computer vision builds the foundation for my future research and unleashes my passion for exploring more fascinating areas.

Reference

Ni, C. (2021), *Learning to Walk Over Structured Terrains by Imitating MPC* [Master thesis, ETH Zurich]. https://chaofiber.github.io/data/master_thesis.pdf

Schmid, L., Ni, C., Zhong Y., Srinivasan, S., Cadena, C., Siegwart, R., and Andersson, O. (2021). *Learning Sampling-based Exploration Planning*. Unpublished manuscript, ETH Zurich, Zurich, Switzerland.