Methods for Scalable and Safe Robot Learning

Robots are increasingly expected to go beyond controlled environments in laboratories and factories, to enter real-world public spaces and homes. However, robot behavior is still usually engineered for narrowly defined scenarios. To manually encode robot behavior that works within complex real world environments, such as busy work places or cluttered homes, can be a daunting task. In addition, such robots may require a high degree of autonomy to be practical, which imposes stringent requirements on safety and robustness.

The aim of this thesis is to examine methods for automatically learning safe robot behavior, lowering the costs of synthesizing behavior for complex real-world situations. To avoid task-specific assumptions, we approach this from a data-driven machine learning perspective. The strength of machine learning is its generality, given sufficient data it can learn to approximate any task. However, being embodied agents in the real-world, robots pose a number of difficulties for machine learning. These include real-time requirements with limited computational resources, the cost and effort of operating and collecting data with real robots, as well as safety issues for both the robot and human bystanders.

While machine learning is general by nature, overcoming the difficulties with real-world robots outlined above remains a challenge. In this thesis we look for a middle ground on robot learning, leveraging the strengths of both data-driven machine learning, as well as engineering techniques from robotics and control. This includes combing data-driven world models with fast techniques for planning motions under safety constraints, using machine learning to generalize such techniques to problems with high uncertainty, as well as using machine learning to find computationally efficient approximations for use on small embedded systems.

We demonstrate such behavior synthesis techniques with real robots, solving a class of difficult dynamic collision avoidance problems under uncertainty, such as induced by the presence of humans without prior coordination. Initially using online planning offloaded to a desktop CPU, and ultimately as a deep neural network policy embedded on board a 7 cm quadcopter.