Name: Wu Keyu

Matric NO.: G1601111F

Thesis Title: Learn to Navigate Through Deep Learning and Deep Reinforcement Learning

Abstract

It is crucial for robots to navigate autonomously in complex environments safely and efficiently. This thesis is to deal with the autonomous navigation problems of mobile robots through deep learning and deep reinforcement learning. It presents four main parts, including a deep learning-based path planning algorithm, a deep learning-based online path planning algorithm, a deep reinforcement learning-based autonomous steering method, and a deep reinforcement learning-based autonomous navigation method.

Firstly, path planning has been extensively studied for decades since it plays a significant role in autonomous navigation. However, the computational time of most existing methods depend on the scale and complexity of environment, which leads to the compromise between time efficiency and path quality. To tackle this challenge, deep neural network-based planning methods have been actively explored. However, despite the success of deep learning-based 2D planner, 3D path planning, which is a significant primitive for quite a few autonomous robots, is rarely handled by deep neural networks. To address this challenge, a novel end-to-end neural network is proposed to realize 3D path planning. By embedding the action decomposition and composition concept, the proposed network is capable to predict 3D actions merely through 2D convolutional neural networks. Besides, the proposed network exhibits high generalization capability and its computational time for each action prediction is almost independent of environmental scale and complexity.

Besides, a novel end-to-end deep neural network architecture has also been proposed to tackle the problem of online 3D path planning in completely unknown cluttered environments. Similarly, it also accomplishes a 3D path planning task via considering multiple value iteration updates approximated by recurrent 2D convolutional neural networks. In addition, a path planning framework has also been developed to better pledge the efficacy and efficiency of the planner through switching among multiple networks that consider different environmental ranges. Meanwhile, the line-of-sight checks are also performed to further optimize the predicted paths. Without any prior knowledge of the environment, the proposed deep learning-based online planner is competent to generate near-optimal paths while its computational time and effectiveness are independent of environmental conditions.

Compared to dealing with the path planning problem separately, it is more superior to achieve autonomous navigation via mapping raw sensor data to control commands directly. In addition, it is also more desirable to learn from experiences automatically and enhance the generalization capability to cope with unseen circumstances. Therefore, an end-to-end deep reinforcement learning algorithm is proposed to improve the performance of autonomous steering in complex environments. As a new variant of Deep Q-Network, the proposed model is capable of deriving steering commands directly and efficiently from raw depth images by embedding a branching noisy dueling architecture. Besides, a new action selection strategy is also introduced to achieve motion filtering by taking the consistency in angular velocity into account. Moreover, the training framework is also meticulously designed to improve the learning efficiency and effectiveness. It is worth noting that the developed model is readily transferable from simple

virtual training scenarios to various complicated real-world deployment without any fine-tuning.

In addition to autonomous steering, a deep reinforcement learning based autonomous navigation method is also proposed. By deriving control commands directly from raw depth images, the developed system is capable to avoid bumping into obstacles, while at the meantime, pursuing to reach the goal positions. Specifically, a dual soft actor-critic method is proposed which trains two networks at the same time. One of the networks is used to derive the desired policy while the other one is adopted to improve the extraction of feature representations from the raw depth inputs. Besides, a joint training framework is also developed by taking advantage of the off-policy nature so as to improve both training effectiveness and efficiency.

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