Enhance Performance of Neural-Network-Based Action Masking for Reinforcement Learning Using Curriculum Learning

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Background

Provably safe reinforcement learning is critical for real-world safety-critical applications. One of the core challenges is to ensure that the agent does not take unsafe actions during both training and deployment. Action masking is a common technique to prevent the agent from selecting unsafe actions [1]. Current methods often rely on hand-crafted rules or heuristics to define and compute safe actions [4, 2], which can be conservative and difficult to scale. Neural networks have shown promise in learning to mask unsafe actions directly from data and then be used for training safe reinforcement learning agents [3]. However, the performance of neural-network-based action masking is limited especially in complex and dynamic environments.

Description

In this thesis, we aim to enhance the performance of neural-network-based action masking for reinforcement learning by using curriculum learning, which allows the agent to learn in a more structured way. By gradually increasing the complexity of the environments and tasks presented to the agent, we expect to improve the performance of action masking networks. Your tasks is to improve and extend the existing pipeline for neural-network-based action masking, implement curriculum learning techniques, and finally evaluate the performance of the enhanced action masking network in an autonomous driving scenario based on CommonRoad and CommonRoad-RL [5].

This thesis offers an opportunity to engage in practical applications of autonomous driving. You will gain hands-on experience in various key areas, including neural networks, motion planning techniques, reinforcement learning, and curriculum learning. The project also aims for a publication in a peer-reviewed conference or journal, providing you with valuable experience in research dissemination.

Tasks

- Familiarize with our current action masking techniques.
- Familiarize with the existing code base for neural-network-based action masking in CommonRoad-RL.
- Enhance the efficiency and performance of the existing action masking pipeline.
- Implement curriculum learning techniques to improve the performance of the action masking method.
- Evaluate the performance in an autonomous driving scenario.
- Documentation of your results.

References

[1] Hanna Krasowski, Jakob Thumm, Marlon Müller, Lukas Schäfer, Xiao Wang, and Matthias Althoff. Provably safe reinforcement learning: Conceptual analysis, survey, and benchmarking. *arXiv preprint arXiv:2205.06750*, 2022.

[2] Roland Stolz, Hanna Krasowski, Jakob Thumm, Michael Eichelbeck, Philipp Gassert, and Matthias Althoff. Excluding the irrelevant: Focusing reinforcement learning through continuous action masking. *Advances in Neural Information Processing Systems*, 37:95067–95094, 2024.

[3] Mirco Theile, Daniele Bernardini, Raphael Trumpp, Cristina Piazza, Marco Caccamo, and Alberto L Sangiovanni-Vincentelli. Learning to generate all feasible actions. *IEEE Access*, 2024.

Supervisor:
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Advisor:
Shuaiyi Li

Research project:
CommonRoad

Type:
MA

Research area:
Reinforcement Learning, Curriculum Learning, Motion Planning

Programming language:
Python

Required skills:
Knowledge of Reinforcement Learning and Curriculum Learning.
Good Python programming skills and experience with PyTorch.

Language:
English

Date of submission:
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[4] Xiao Wang and Matthias Althoff. Safe reinforcement learning for automated vehicles via online reachability analysis. *IEEE Transactions on Intelligent Vehicles*, 2023.

[5] Xiao Wang, Hanna Krasowski, and Matthias Althoff. Commonroad-rl: A configurable reinforcement learning environment for motion planning of autonomous vehicles. In *2021 IEEE International Intelligent Transportation Systems Conference (ITSC)*, pages 466–472. IEEE, 2021.

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