Real-Time Optimal Control Of Quadrocopters Using Deep Representations Of The Optimal State Feedback

Executive Summary

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Picture:

Motivation:

A major challenge in the field of control is to achieve reliable, aggressive, high-speed control of autonomous vehicles. In space, this may involve spacecraft that need to land under harsh conditions, or even – in an extreme scenario – negotiating asteroid debris fields at high speeds. On earth, the exemplar task that draws most attention currently is high-speed autonomous flight of drones. The application of optimal control on-board limited platforms has been severely hindered by the large computational requirements of current state of the art implementations. In this work, we introduced and applied a deep neural network to directly map the robot states to the optimal control actions to overcome this limitation. The approach has been illustrated with high-speed flight of a drone with heavily constrained onboard processing, and can generalize to other platforms such as spacecraft that have similar restrictions.

Methodology:

To move the optimal control policy onboard, 250,000 optimal trajectories are generated offline based on the optimal control theory. Then, a G&CNet --- a neural network trained to learn this dataset --- is computed. G&CNet predicts the required optimal thrust directly which will be transferred to the optimal pitch rate acceleration and sent to the controller, and thus can be seen in the context of non-Linear MPC. The G&CNet is first tested in simulation with a simplified quadrotor model. The simulation result shows that the proposed G&CNet can steer the drone to the target with the trajectory close to the theoretical optimal trajectory. At last, the G&CNet is tested on a real drone at the MAVLab at TU Delft. The result shows that the G&CNet works well in the real-world and needs less time to navigate the drone to the target than a commonly used method.

Results:

- The proposed G&CNet, which is a type of MPC, can navigate the drone to the target in the real world. The drone's trajectories are close to the theoretical optimal trajectories which proves the feasibility of running the optimal controller onboard.
- The drone's aerodynamics and the input constraints are considered when generating optimal trajectories. From the real-world flight result, it can be seen that the input data of the drone are kept within the boundaries which is essential to guarantee the tracking performance and the stability of the controller.

Publications:

- Li S, Ozturk E, De Wagter C, de Croon G C H E, Izzo D. Aggressive Online Control of a Quadrotor via Deep Network Representations of Optimality Principles [J]. IEEE Robotics and Automation Letters. (submitted)

Highlights:

There are two directions for future work. Firstly, this work does not include the actuators' dynamic. When ϵ is set to a small value, which leads to a bang-bang controller, the drone cannot track the reference trajectories well and even loses the stability. Hence, to model the actuator dynamics is a direction to improve the work. Secondly, the flights are still in 2D space in the current work. To extend the current work to 3D space is another interesting direction.