A Machine Learning alternative to PID controllers

Physical Sciences

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CS229 - Project proposal

Application

Quadcopter control using Reinforcement Learning (RL) or Deep Learning (DL) - replacing traditional PID controllers

Motivation

Current quadcopter stabilization is performed using classical PID controllers. These controllers usually perform well, but can lead to poor performance when non-linearities are introduced, which is the case for quadcopters in a clustered environment. Our project intends to implement an RL or DL controller for quadcopter stabilization. To effectively compare our proposed algorithm with a classical PID controller, we intend on testing the stabilization of an inverted pendulum that would be mounted on the drone. The angle θ between the inverted pendulum rod and a vector normal to the ground will be a measurement of how stable the drone is.

Method

- *Simulator:* A quadcopter simulator will be implemented in Matlab/Simulink. Various sources for such simulator are available, and not much time should be needed to implement the simulator + PID controller that are required to train the Reinforcement Learning or Deep Learning algorithms. Precisely, the simulator will be based on the dynamics outlined in the paper by Bouabdallah et al. [1]
- *Reinforcement Learning:* First, a reinforcement learning algorithm is considered to develop an effective controller. The reward associated with every action could be modeled as $\exp(-\theta)$ (where θ is the angle between the inverted pendulum rod and a vector normal to the ground). To explore the state-space, the ϵ-greedy method could be used, where the policy from a PID controller will serve as a reference for optimal control.
- *Deep Learning:* Another possible approach is to replace the PID controller with a controller trained using Deep Learning as outlined in the paper by Cheon et al. [2]. The main idea would be to train the Deep Neural Network on the input/output data from the PID controller in operation.

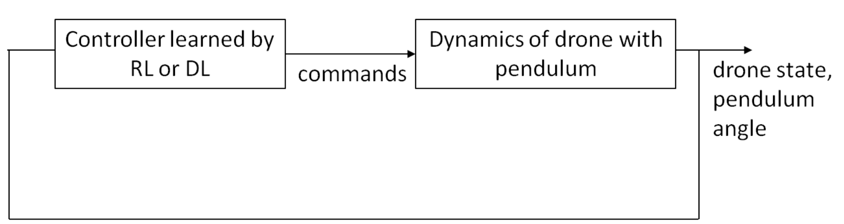

Figure 1: Illustration of the problem setup

Intended experiments

- Simulations on Matlab/Simulink will be performed first to extract the necessary data to train our algorithm and later on to demonstrate its performance compared to a classical PID controller. Some metrics for the performance include : time response, overshoot, steady-state error.
- If resources are available (time and equipment), we intend on testing our algorithm on a real drone. Several labs at Stanford (ASL, SISL, ADL) have the equipment required for such tests.

Pointers to a relevant data set or prior research on the topic

- Cheon et al. [2] show how a PID controller can effectively be replaced by a two layer Neural Network trained using the Deep Belief Network algorithm. The resulting controller seemed to work at least as good as the PID controller. The training data for the Neural Network is taken from a tuned PID controller operating a motor.
- Wakitani and Yamamoto [3] present a data-driven PID. The way in which collection of input and output data from the PID controller is performed seems like a suitable approach to obtain our training data set.
- Hehn and D'Andrea [4] explore a control approach to the classic inverted pendulum problem, but mounted on a flying quadcopter. The dynamics of the quadcopter and pendulum are explored and a control model is proposed and evaluated. They end the paper suggesting a Machine Learning approach could be applied.

References

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[2] Kangbeom Cheon, Jaehoon Kim, Moussa Hamadache, and Dongik Lee. On replacing pid controller with deep learning controller for dc motor system. *Journal of Automation and Control Engineering Vol*, 3(6), 2015.

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