**Adaptive Position Control of a Levitating Ball**

Course Project - Project Description

ELG7113 - Machine Learning for Adaptive and Intelligent Control Systems

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System Description

*“Each group has to submit a short report describing the system selected for the project, and a preliminary description of the type of analysis that is going to be conducted. Feedback will be given.”*

A picture containing text, clock

Description automatically generatedThe system consists of a ball in a vertical tube with a fan and lidar sensor at the top. The objective is to control the response of the ball ultimately having it settle at a certain settling point. The system is shown in Figure 1. The input to the system is the desired vertical position, with the output being the ball’s actual position, . The system will convert the desired position into a control signal to adjust the duty cycle and fan speed. Changing the fan speed will adjust the force balance, resulting in a net force either up or down, accelerating the ball. This is the method in which the ball’s position is controlled.

Figure : Schematic representation of the system

Shape

Description automatically generated with medium confidence

Figure : Block diagram of the adaptive system with the parameter estimation and control design loop

Diagram

Description automatically generated

Figure : Block diagram representing the control structure of the model-reference (model-free) adaptive control strategy

Problem Formulation

Aerodynamics is a notoriously nonlinear field of study which has perpetuated the need for the development of control theories to deal with nonlinearities, uncertainties, and process variations. In the past control approaches have included gain scheduling, adaptive control mechanisms and model free approaches have been used to deal with the difficulties encountered in such projects. In this study, we propose the implementation of a modeled adaptive controller as a baseline for comparison, following which a measurements-driven model-reference approach will be implemented and compared to the adaptive controller.

The need for such control systems is driven by the fact that traditional control techniques rely heavily on an accurate and certain model with limited process variation even in robust control designs. Further, the limitations in PID type control are there application. Generally, PID family controllers are used in scenarios where the plant changes states and maintains that state. For applications where optimal tracking is required, other approaches are more readily suited.

Dynamic Model

The dynamics of ball are derived in similar fashion as seen in [1]. This model consists of a force balance between the drag force, buoyance force and gravity force. From this model, the acceleration can be calculated and then used to estimate the ball’s position and velocity. ~~The estimated position and velocity can be compared to the actual values as well as the desired velocity~~.

#insert equations and math stuff here

ADD HERE SIGNAL IDENTIFICATION

Work Plan

The overall plan is to model the system and implement multiple adaptive control structures, comparing their performance to each other as well as a baseline set of responses from a previous implementation of this project.

1 - Model the dynamics of our system in accordance with the literature and implement control strategies from the linearized model (i.e. empirical tuning and gain scheduling)

2 - Perform parameter estimation on the model to increase the correlation of the constantly updating model and the physical output.

3 - Perform system identification on the physical system with the purpose of control

4 - Implement multiple adaptive control structures (example: model reference control, model-free control, self-tuning regulator).

5 - Compare the performance of the implemented control structures

Performance metrics include overshoot, settling time, ….

Bibliography

[1] A. Tootchi, S. Amirkhani, and A. Chaibakhsh, “Modeling and Control of an Air Levitation Ball and Pipe Laboratory Setup,” in *2019 7th International Conference on Robotics and Mechatronics (ICRoM)*, Tehran, Iran, Nov. 2019, pp. 29–34. doi: 10.1109/ICRoM48714.2019.9071827.