Use of Model Predictive Control (MPC) for Rocket Altitude Correction

Nikhil Peri, Anthony Lin, Manit Ginoya, Paul Buzuloiu
uOttawa Rocketry Team
{nperi104, alin102 mgino015, pbuzu025}@uottawa.ca

***Abstract*—**

KeywordsModel Predictive Control, Aerospace.

I. Introduction

Rockets unlike other aircraft have high speed and dynamic flights, as a result rocket control systems have to be extremely responsive and precise. Classical control systems based on observed sensor feedback would not be able to meet the demands of rocket flight since the latency between plant actuation affecting the the physical world and detecting that change through sensor observations is too slow for such dynamic flight enviroments. Model Predictive Control (MPC) solves these problems by introducing state estimation. This process involves maintianing a kenetic

II. Airbrake Model

III. Model Predictive Control

The complexity of rocket flight partially arises from the numerous states required to fully define an entire set of dynamics. These states include acceleration, velocity, position, orientation, angular speed and angular acceleration of the rocket in all three spatial dimensions. Additionally, the states related to the actuators (in this case, the servo motor controlling the airbrakes) must also be considered. Desiging a classical controller or even a digitally implmented classicial controller would bring along several inconveniences; for this reason, a model predictive controller was considered and implemented.

The major concept of model predictive control is to maintain a real time simulation; This simulation's role is to produce a prediction of future system states using feedback from sensors and the system's current states. For the case of achiving a particular target altitude by deploying airbrakes, the MPC will produce a predicted final altitude every control loop. Using this predicted final altitude, the error between the predicted final altitude and the desired final altitude will be calculated. The final part of the MPC process is to map the calculated error to a specific (whether heuristic or deterministic) control signal that will be sent to the airbrake actuator.

Figure 1 is the fully defined control system diagram corresponding to the description provided above. Running through the control schema yeilds the following sequence of events: sensors are read, filtered and fused, states are estimated, trajectory is predicted, final altitude error is determined, control signal is generated, signal is sent to actuator driver, actuation occurs which affects rocket flight.

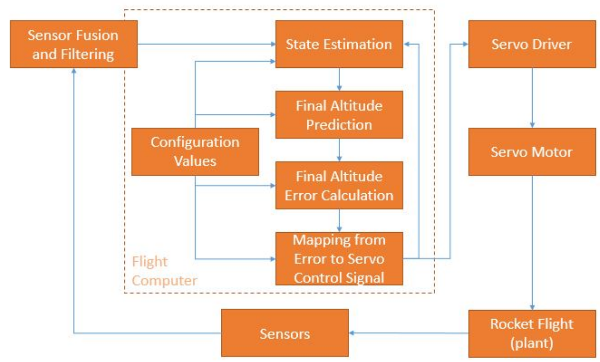

Fig. 1: Overall Control Diagram of airbrake system

When comparing figure 1 to a typical control systems diagram, the input to the system seems to be missing; This input (the desired final altitude) is merely hidden away as a part of the digitally implemented configuration values. Some important inferences of the presented control diagram include understanding that the configuration values include all phycial rocket parameters, as well as the desired final altitude. Therefore, the presented figure is related more to the physcial implementation than to control theory notation.

IV. Imeplementation

Here, each block residing withing the flight computer as shown in the diagram presented in figure 1 is defined further to provide insight into the implementation of this system.

A. *Sensor Fusion*

B. *State Estimation*

C. *Final Altitude Prediction*

D. *Final Altitude Error Calculation*

E. *Mapping from Error to Control Signal*

V. Conclusion

In this brief, an implementation of model predictive control is presented for a custom airbrake system to be deployed on a sounding rocket. The convenience of using MPC for this specific application is shown. Furthermore, and with some modification, it is shown that the implemented MPC can be deployed on cheap electrical hardware.

VI. ACKNOWLEDGEMENT

The authors would like to thank the University of Ottawa for continued support of the rocketry team. Additionally, specific thankfulness is issued to professor Habash and the teaching assistants of the ELG 4157 course.

REFERENCES