ME C231 Project Ideas

This document provides some guidelines for two recommended projects that are based on the Fall 2017 MPC midterm exam. Note that the midterm exam and related data files are posted on bCourses under the assignment titled "Find Teammates and Project Idea."

Each recommended project has two parts:

- **Part (a)** is taken directly from the 2017 midterm. This part is meant to help you get started on the project topic.

- **Part (b)** builds on the previous part but should be more exploratory. We are providing a few ideas here. Note that the ideas are not fully elaborated; you can come see us to discuss them further.

Here are some more details on the form of the deliverables:

- The 3-page report and 5-minute video should focus more on Part (b) rather than on Part (a).

- In addition to the three pages, the report may include a cover page (including project title, team member names, link to the video) and a page for references. But, all of the actual content must fit within three pages. No appendices. There is no recommended template, page margin or line spacing specifications or report structure but please use at least 12-point font size.

- The report and video are due at 11:59PM on Friday, December 14, 2018. A submission page will be created on bCourses where you can submit the PDF file of the report.

Learn a lot and have fun.

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1. **Controlling a Rocket Landing**

   In the 2017 midterm exam this topic is split into three separate problems:

   Problem 3: Path Planning with Constrained Finite Time Optimal Control via Batch Approach

   Problem 4: Path Following with MPC

   Problem 5: Reachability Analysis

   (a) Complete problem 3.

   (b) Below are some ideas that build upon part (a). You can pick one, more of them, or just get inspired and propose your own.

   - Solve problem 3 again but this time modify the dynamical model and CFTOC by considering the use of grid fins as an additional input. For example, see `https://www.spacex.com/news/2015/08/31/grid-fins`.

- – The grid fins are primarily used to manipulate the first stage's lift during the reentry phase (`https://www.flickr.com/photos/spacex/16892430560/`) for a more precise landing (e.g., to land on the surface of the "Just Read The Instructions" drone ship). The idea here is to use them in the landing phase to manipulate the drag force on the first stage for better control of the descent velocity. Note at the 32-second mark of the video at `https://youtu.be/bvim4rsNHkQ`, the September 2014 landing attempt (without grid fins) failed in part due to running out of fuel while attempting a landing with only thrusters.[1]

- Repeat Problem 4 and Problem 5 with the new dynamical models (with grid fins) . How would you modify the CFTOC (i.e., grid fin input constraints, objective function that considers minimum-fuel)? Can you prove the value of grid fins using your model and the tolls you have learned in class?

- Or, instead of using MPC for the path following, use Loopshaping to design a path following controller.

- Add model uncertainty, for example, in the form of wind and/or control delay and study the performance of your controller.

- Note that a full 6 degree-of-freedom model of the rocket would consider translational motion in three directions and rotational motion about three axes (e.g., roll, pitch, yaw). For simplicity, you can consider a reduced rocket model describing only "vertical" motion and rotational motion about a vertical axis, as is done in the midterm exam problem. The grid fins would also be modeled to have a single angular motion (e.g., roll motion). In doing so, we assume that we have a wide enough landing area and are not concerned with landing on a drone ship.

2. **Controlling a Train**

   In the 2017 midterm exam this topic is described in the following problem:

   Problem 6: Constrained Finite Time Optimal Control via Dynamic Programming

   (a) Complete problem 6.

   (b) Consider the following ideas that build upon part (a).

   - Expand the idea to the problem of optimally controlling train platoons. You may read the following paper that is currently in review for more details:
     - "*A model predictive control approach for virtual coupling in railways*" can be downloaded from bCourses.

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[1]The grid fins were introduced on production first stages in the year 2015 with the first successful landing in December 2015 after at least three years of development and testing.