ENGR 580: Project handout #1

September 2023

Design project (see course syllabus)

- Students will choose a *nonlinear physical system* that they are interested in for which a *multivariable control system* is required. During the term, you will use the techniques learned in the lectures and studied in the book to model, analyze and control the system you choose.
- You may work alone or with one partner. If you work with a partner, only one project report will be accepted and your team work will be evaluated.
- The TA will be available for project support as detailed in the project handouts.
- Your project report needs to be submitted through Canvas in PDF format with ONE m-file that reproduces the results described in the PDF. You PDF should follow the formatting requirements described in the project handouts.
- Late submissions of the report will be penalized with 10% in the first week. Submissions that are more than a week late will not be accepted.

Updates related to the project will be posted on Canvas or in subsequent handouts. If applicable, the latest updates will supersede any previous communication.

Introduction to ENGR 580 design project

Your project will contain *two parts*. The first part (*Part A*) consists of exercises related to a sample project, which will be common to everyone. The second part is your design project (unique to you/ your group, *Part B*). Handouts will be provided throughout the course, which will describe the sample project and exercises, and guide you through your design project.

A final project report will be worth 40% of your grade course. If you work with a partner, only one report will be accepted. Your will report your work in three parts:

Report part A Part A will contain your work and answers to the exercises related to a sample project.

Report part B Part B will report on your design project.

Code (part C) ONE m-file that reproduces the results described in your report.

Report formatting requirements

- Your PDF must be formatted according to the IEEE two-column template.
- Use of Latex over Microsoft word is recommended. Latex is preferred for reports and papers containing mathematical characters, and allows for easy inclusion of matrices, vectors etc. You can use any editor that is compatible with Latex. Good ones can save you a lot of time.
- Part A and part B must be clearly labeled.
- Subparts (following the handouts) must be clearly labeled.
- Your report must be *brief* yet *complete*.

m-file formatting requirements

You need to ensure that the results that you report are *reproducible*. You will need to provide an m-file that reproduces all the results and figures included in your report, i.e. running this m-file should generate all the results in the command window or in a figure. You can use additional m-files that contain code or functions to keep your work structured. Any of such files or functions need to be called from the m-file that reproduces the results. For example, you can submit main_yournames.m that calls handout1_yournames.m to generate the results related to handout 1.

Overview

For your design project you will select a real-world system and use the tools learned in the course to analyze your system and design controllers for it. At the end of this course you will have:

- Provided a functional overview of your system and described the relevant parameters/ characteristics of your system. You will also have developed a nonlinear model of the system dynamics and linearized your model.
- Demonstrated the open-loop response of your system.
- Evaluated the stability of your system.
- Evaluated the controllability of your system and designed a state-feedback controller.
- Evaluated the observability of your system and designed an observer and output feedback controller.
- Clearly presented your results, justified your design decisions and identified the next steps to realize your design in the real world.

In parallel to your design project, you will also do exercises related to sample projects. Since your design projects are unique, the intention of the sample projects is to provide a common point of reference for the entire class.

1 Choosing a real-world system for your project

You will do some research and choose a system for your design project. Many students find this a challenging task. To get you started, resources are provided below.

Any system you choose should satisfy the following requirements:

- Your system needs to be based on a real-world system. Choose something that you could implement in real life if you were given the resources.
- Your system needs to have more than 2 states. Hint: You can interconnect several second order systems to fulfill this requirement.
- Is not studied by another student/group. Use the discussion board on Canvas to post the title of your design project to make sure it is unique. In the unlikely chance that two groups choose the same system, they must agree to make changes to make their project distinct.
- Your system needs to have more than one input and preferably more than one output (multi-input multi-output). Hint: You can again interconnect systems to achieve this requirement.
- Your system must be nonlinear. Real-world system likely satisfy this to some extend. If you find a linear approximation of a system that you are really interested in, you can augment your model with at least one nonlinearity. As an example, can your actuator apply infinite control effort or does your control input saturate? Perhaps there is friction or damping that is nonlinear?
- Your system must be approved by the course instructor and the TA. For this, you need to hand in a functional overview of your system and described the relevant parameters/ characteristics of your system, a description and derivation of the nonlinear model of the system dynamics and of the linearized model. It is advised to discuss your choice with the TA as early as possible, and to hand in this overview early.

1.1 Resources

You can choose a system that you are interested in. This can be related to your MSc or PhD project if appropriate. If you do not have such a project, you can find inspiration from:

- Textbooks. The UBC library has many textbooks on state-space systems, modern control, and nonlinear systems. Most books have example systems that you can choose or use for inspiration. Some suggestions include:
  - C. W. De Silva, Mechatronics: A Foundation Course. CRC press, 2010.
  - W. S. Levine, The Control Handbook. Chapman and Hall/CRC, 2010.
  - S. H. Zak, Systems and Control. Oxford University Press, 2003.

  The UBC library also has many books available electronically through the library website.
- Journal or conference articles. Use Google Scholar of the UBC library search feature to find articles related to key words. You may need to be on campus to access most journals. Some suggested journals are Mechatronics (Elsevier), IEEE/ASME Transactions on Mechatronics, and IEEE Transactions on Control Systems Technology. Many papers describing control applications will include a system and model description.
- Physics, but remember: this is not a modelling course. This can get complicated so don't pick something crazy or expect the TA/instructor to derive the equations for you! If you go this route, it can often help to start with a functional block diagram and then build up the equations based on it.

1.2 Discussion points to include in your overview submitted for approval

1. Provide a description of your chosen system which can include background, motivation, functional explanation, specific technologies (sensors and actuators that you will use for feedback and control). Include picture(s) or diagram(s) to visualize your system.
2. Present a nonlinear state-space model of your system as well as at least one linearization. Make sure the states and parameters are clearly explained in terms of the physical system. Choose realistic numerical values for any parameters in your model. Ideally you will not derive these equations from first principles (this is not a modelling course!) but you should explain how the equations came about.
3. What are the major assumptions or limitations of your model.
4. What are the references that you used.

Note that this submission can serve as your model description in part B of your design report.