EE 407 Process Control - Fall 2018
Project A-La-Carte Menu

Deadline for project choices: 23:55, 29.11.2018

Project Demonstrations: 22.01.2019

1 Starters

We have a strong belief that getting one's hands dirty by designing and implementing control systems using real equipment is the only way to acquire a deep understanding of the operation and performance of control systems. With this in mind, we have coined a number of "menu" items that you can choose from as your term project topics.

You are asked to form a team of four students to work together on this project. Then, you are supposed to send an e-mail to *kumru@metu.edu.tr* proposing the names of the group members and a list of **all** projects sorted from the most desired to the least desired. Each menu item is planned to be assigned to at most four groups and the assignment will be performed on a first come first served basis. Hence, it is better not to delay your decision and submit it as soon as possible.

The idea is that each project alternative is loosely defined but self contained: They can be implemented and tested with reasonable effort and at a very modest cost (shared by team members). They are also expected to serve as valuable know-how in your EE493-EE494 projects that needs feedback control. You are expected to build a hardware setup employing suitable sensors and actuators to realize the assigned project. Then, you are to apply some of the control methods covered in the lectures and come up with a procedure and performance results that can be measured.

2 Mid-Course

The project output will be in the form of a demonstration, project report and video. The report will be in the form of an "Experimental Procedure Sheet"(for the instructor) where you will describe the system (setup), the theory (model of plant, sensors and actuators); and then write down the "Experimental Procedure"in the form of well defined steps, questions, requests for comments etc. This experimental sheet will also include answers to all these questions, results of experimental steps and comments on the results. Evaluation will be based on the operation of the setup, the quality of the questions as well as the results and discussions. The evaluation will be done via a "rubric" that we will share soon. In your video, you will record a quick demo (3-5 min) of your project by introducing the setup you built and illustrating the performance of your control algorithms.

Note that you are expected to

- Define clearly the measurables of your system,
- Apply different control techniques,
- Provide a comparison of the methods you implement,
- Present and analyze continuous/discrete-time performance curves of your control system,
- Show the disturbance rejection performance.

3 Main Course

Here are the alternatives for project topics:

1. **Temperature Control in a Simplified Laptop Thermal Management Problem**
   In this project, the aim is to control the temperature of a specific point on a circuit board. The temperature will be measured via a thermistor, and the FET transistor will be the heating element. Heat generated by the transistor is transferred to the thermistor by radiation, convection, and conduction. Additionally, a small-sized fan with a continuous voltage input is to be utilized to accomplish a controlled cooling process. The control algorithm is supposed to manipulate the voltages fed to the transistor and the fan to control the temperature sensed by the thermistor.

2. **Miniaturized Water Level Control of Coupled Tanks with an Electric Water Pump**
   In this project, you are to control the water level in a small tank (such as an typical bucket) which is coupled to another tank. The only source of inflow to the tank which is the subject of the control problem is this coupling while an electrical pump is able provide an inflow to the other tank. An example realization of a such system is given in Fig. 1. In this system, the pump can deliver water to the Tank 1 while the problem is to control the water level in the Tank 2. The coupling between the tanks is established by means of a leakage through the orifice at the bottom of the Tank 1. Note that any other system configuration (such as placing the tanks at the same level and connecting them via proper pipe) can be accepted as long as it does not violate the main specifications.

   You are not constrained in terms of the measurement device to measure the water level. You can choose any sensors that fits to your design from a wide range such as ultrasonic, infrared, pressure sensors and even cameras. You are allowed to use only one low-cost mini electrical water pump as the actuator of the system.

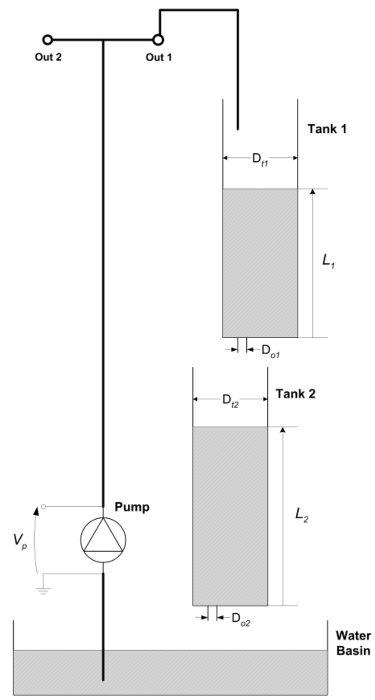

Figure 1: An example configuration of the coupled tanks, [1]

3. **Design of a Ball and Beam Setup**

   Ball and beam system has been widely used as an exciting setup to design and validate a variety of control algorithms. Although quite different variations of the system have been constructed, an example system is illustrated in Fig. 2, the main objective is to control position of a ball that is free to roll on a beam. You are allowed to control tilt angle of the beam with a DC motor (and auxiliary mechanical components if desired). Also, you need a way to sense the ball position by a resistive, ultrasonic or capacitive sensor.

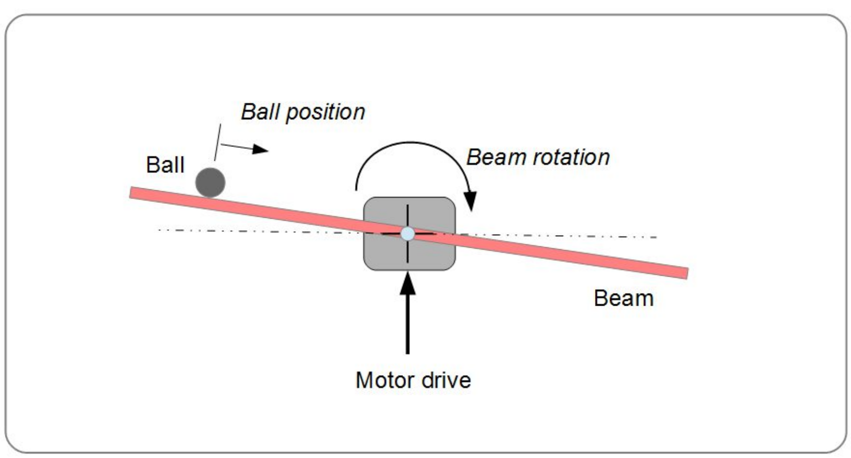

Figure 2: Diagram of a Ball and Beam Setup

4. **Differential Drive Line Follower**

   The aim of this project is to design a controller for a miniature differential drive line following robot. There will be two DC motors & wheels as actuators, two H bridges (or suitable motor driver IC) as your final control elements and an array of IR sensor(s) to detect the line. The line to be followed should not be a straight one; a piecewise linear and continuous path is acceptable. Controller performance under different conditions (e.g. added mass, changing slope, changing speed) should also be investigated. Demonstrating that your robot can follow a line is not sufficient on its own to convince us of your control system performance. You are expected to provide performance curves that allow further analysis.

5. **Design of a Blood Pressure Monitor Controller (Closed Loop Pressure Control)**

   The idea behind a blood pressure monitoring device is to quickly reach a desired pressure (follow unit step reference input) with preferably little overshoots (pumping up phase) and then decrease this pressure linearly with time (pumping off phase). You are to design a closed loop pressure controller where your system is required to perform well to both of these two types of inputs: unit step and unit ramp. A miniature air pump and a voltage controlled valve are your actuators (for pumping up and off phases, respectively), pressure in a constant volume container is your controlled variable and a pressure sensor of your choice is the measurement device.

6. **Ball and Hoop Setup**

   Ball and hoop system is another commonly employed experimental setup in control education. It is able to exhibit diverse dynamic characteristics establishing an effective playground for the investigation of control systems. The setup basically comprises of a ball that is free to roll on the inner surface of a rotating hoop as depicted in Fig. 3. The hoop is mounted vertically from a pivot point at its center and there is an electric motor rotating the hoop about the pivot. You can find an impressive example achieving advanced modes of control in [2].

   The ball and hoop system drew a lot of attention since the dynamics shows close resemblance to the dynamics of liquid in a moving container. Stabilizing liquid in a mobile container to prevent slopping and spills is a substantial and challenging problem while any failure of the control system may lead to catastrophic outcomes. For example, the motion of the propellant was said to be influential in one of the failures of SpaceX's Falcon 1 rocket, [4]. In this context, we want you to implement and compare control algorithms to stabilize the ball at the bottom of the hoop while rejecting any disturbances from the environment.

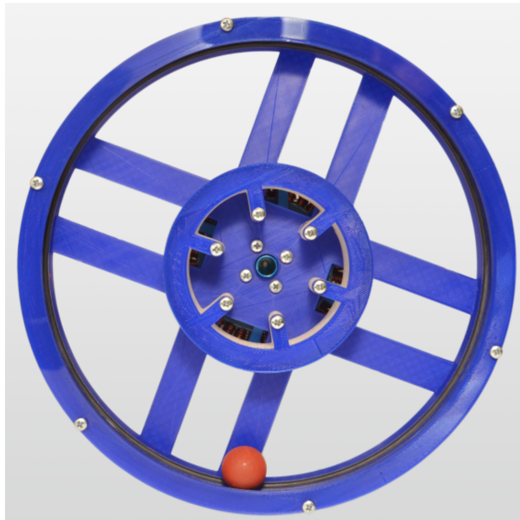

Figure 3: The photo of an example ball and hoop setup, [3]

4 Dessert

Microcontrollers, electronic parts, sensors and actuators are increasingly available at low cost for the engineer as well as the hobbyist like never before. There are many on-line sources of parts and sensors both in Turkey and abroad. Buying from Turkey is usually much faster. The exciting and fun part will be to see a working system that you have built: A high performance controller built in a digital microcontroller. Another possible achievement will be that the document you have generated may become the basis for a EE407 experiment for the future generations of students!

Best from us, the EE407 team. We hope you will enjoy what you and have some fun as well.

References

[1] "Coupled Tanks Example," https://www.quanser.com/products/coupled-tanks/#overview.

[2] "A ball and hoop system realization," https://youtu.be/484GN4KBQnc.

[3] M. Gurtner and J. Zemánek, "Ball in double hoop: demonstration model for numerical optimal control," *IFAC-PapersOnLine*, vol. 50, no. 1, pp. 2379–2384, 2017.

[4] "How Not to Land an Orbital Rocket Booster (SpaceX)," https://youtu.be/bvim4rsNHkQ.