EE302 Feedback Systems

Bonus Project Guidelines

Spring 2018

1. Scope

The purpose of the bonus project is to give the interested students a chance to experiment with easily affordable microcontroller hardware implementations of basic control systems. This document outlines the required hardware and software for such an implementation. Specific steps will be described in project leaflets through the term.

2. Introduction

As part of this project, you will implement possible control approaches for controlling the positional angle of a one axis (one degrees of freedom) “robot arm”. The arm will have a small weight on its tip and the motor will produce a torque acting on the arm working against gravity. By using a simple Arduino microcontroller, a motor driver circuit as well as a simple output measurement circuitry, you will be able to try some of the theory in EE302 in a real life example application. Figure 1 shows a simple sketch of the control problem and Figure 2 shows its top-view.

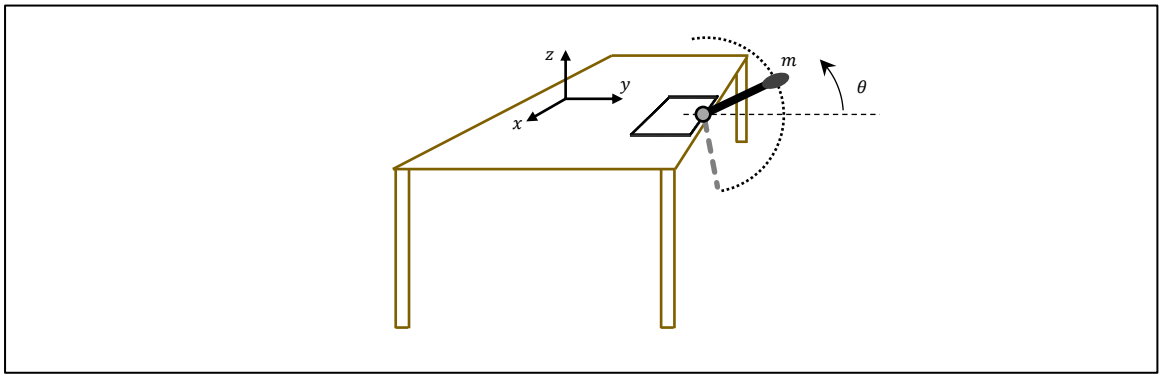

Figure 1: A sketch of the control setup placed fixed on the edge of a table. The x-y plane coincides with the table surface. The z-axis is perpendicular to the table surface pointing upwards. The rigid arm rotates freely in the y-z plane. The axis of rotation is the x-axis. There’s a small weight of mass m attached at the tip of the arm and the gravity yields an acceleration of the arm towards negative θ direction. The torque supplied by the dc motor is in the positive θ direction.

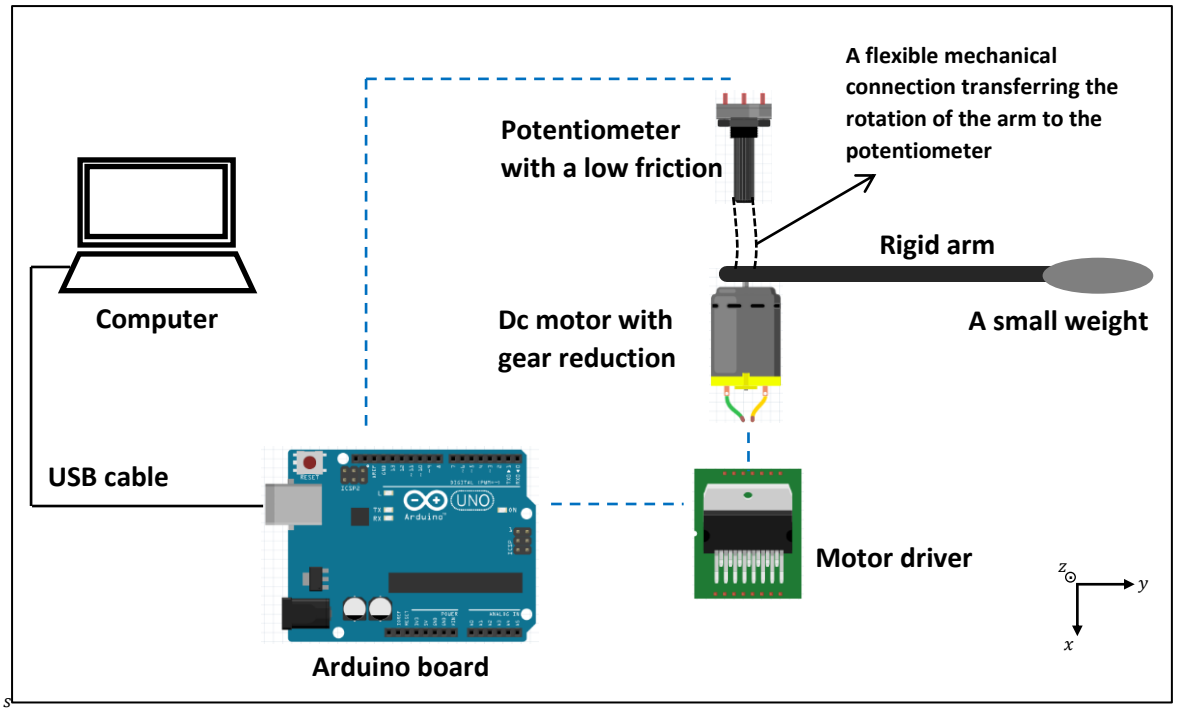

Figure 2: Top view showing the motor and potentiometer. The axes are the same as in Figure 1 and the z-axis sticks out of the paper towards the reader. The motor is rigidly attached to one end of the arm and any rotation of the motor is translated to rotation of the arm. A potentiometer is also connected, possibly through a flexible link to the arm and acts as a variable voltage divider. The output voltage is read by the microcontroller as a feedback signal corresponding to the output arm angle θ.

We will provide you with some code templates for the controller software on the Arduino side as well as interface software on the computer side. We hope that the proposed hardware and associated software will provide an excellent and affordable way to experiment at home with the theory you learn in class. You will have the chance to observe many of the interesting behaviors that a feedback system may exhibit. The single most important aim of this optional project is for the interested student to experience that with today's computational hardware, control theory is exciting, simple and affordable to implement.

3. Hardware

As shown in Figure 2, the project hardware consists of the popular and accessible Arduino microcontroller, a motor driver board (such as an L298 driver IC and its heatsink!), a 5V-3A or 12V-2A switching power adapter (depending on our gearhead motor choice), a small number of standard electronic components and a "plant" consisting of a swinging arm rotated by a gearhead dc motor. Figure 3 shows the pictures of some sample components.

The aim is to control the angle of the arm in a closed-loop configuration by using the torque generated by the motor while measuring the arm angle through the potentiometer voltage. The input to the motor is a current amplified (motor driver) PWM generated DC voltage. The control algorithms will be implemented and will be executing entirely on the microcontroller in real-time. A graphical user interface on the PC will provide access to critical performance signals and will allow you to change controller design parameters.

Figure 3: Illustration of some hardware components

4. Software

The software involves two components: The “firmware” component resides on the microcontroller and consists of an implementation of the chosen “controller” (such as P, PD or PID) as well as some auxiliary functions to record the relevant variables for later observation. The firmware program will be written in the C-like language of the Arduino IDE. This will be mostly provided to you. The second part is written in Python and resides on your PC to communicate with the microcontroller to change/set configurable parameters, retrieve recorded signals and plot them for observation.

5. Project Timeline and Conduct

Most of the theory required for this hardware implementation (rotational mechanical systems, dc motor models, and analysis of LTI systems and design of PID controllers) will be covered early in our course. The missing pieces are an overview of some of the “discrete-time” concepts and the simplest approach for its implementation as well as linear approximations to nonlinear systems. We will distribute the steps throughout the term by means of two “stages”. The first stage will be associated with an intermediate report (to be graded). The

second stage will be concluded towards the end of the term with a “Final Report” where you will be summarizing your results and a “Working Demo” where your team will be demonstrating your setup. Projects will be conducted by teams of three students who will share a hardware setup and work together on the two stages of the project.

It is important that you allocate time in advance to allow both for your experiments as well as the writing of both reports.

6. Project Evaluation

Evaluation criteria will be based on specific steps that will be detailed as part of the stage “leaflets” to be made available during the term.

7. Quick Start Guide

You should use this guide to start exploring the project topic, hardware and software. For this you may use the following steps:

1. Use YouTube to explore similar project implementations and find out about similarities and differences (suggested starting keywords: dc motor, Arduino, position control, servo)

2. Examine basic Arduino programming projects, including toggling LEDs, reading potentiometer voltages, generating pulse-width-modulation (PWM) signals.

3. Examine hardware suppliers given in Section 8 below. Consider purchasing your Arduino board, and exploring its GUI and programming environment. You can have a quick start by compiling and running example programs that are directly available in the IDE.

4. Explore possibilities for project specific components such as gearhead motor and measurement potentiometer. We will later specify some of these components.

8. Some Hardware Suppliers

- http://www.robotistan.com (Arduino kits, L298 boards, sensors, many other “maker” stuff)
- http://www.robit.com (similar to above)
- Ulus – Konya Sokak (Ankara’s electronics heaven – all electronic components)
- http://gittigidiyor.com (especially 5V, 3A adaptor and motor-housing-propeller set)

- http://n11.com (similar to above)
- http://www.aliexpress.com (almost anything but with time delay)

9. Parts list

1. Arduino Uno (clone) + USB cable

2. L298D Motor Driver IC board with heatsink.

3. 10K or 5K or 1K (low friction) potentiometer as a voltage divider.

4. Jumper cables (pre-stripped Male/Male + Female/Male)

5. Breadboard,

6. DC motor with gear reduction.

7. 5V or 12V DC Switching Adapter (15 Watts – 3A or 2A minimum), and its connector to connect it to a circuit