Lab 4 A

Goals

- Learn how to identify static and dynamic (viscous) friction of the Haptic Paddle.
- Compensate for the identified friction and gravity in the control program.

Required solutions to submit in the report (will be graded)

- Try to provide a brief and intuitive explanation for the terms stiction, Coulomb friction, and viscous friction (no equations required).
- Show your implemented friction and gravity compensation to one of the assistants or hand in a video showing the friction and gravity compensation, as described in exercise 2c.

Deadline

Hand in a zip file with the required documents (Lab 4 A & B) to the dedicated assignment on Moodle by **Tuesday 30.11.2021:**

- name all documents: "lastname1_lastname2_lab4.XYZ"
- single PDF with your solutions for Lab 4 A & B (no Excel files, no separate Matlab figures)
- video of friction and gravity compensation (if not in lab session)
- your VIs

Important Note (for the entire exercise)

Ensure that all the VIs start by writing V_0 to the motor and stop by writing V_0 to the motor, i.e., the motor does not generate any torque when you start and stop your program. Also, be sure to stop your code (your timed loop) with a stop button you implement and not with the red stop button in LabVIEW.

0. Understanding of different friction components

Make sure that you understand the terms stiction, Coulomb friction, and viscous friction. Double-check with an assistant if necessary.

1. Identification of stiction torque and viscous friction torque

a) Identify stiction torque

- Build a LabVIEW VI to increase the motor current in small steps until a movement is detected (hall sensor: Δx > sensor noise, Lab 2 A). Write down the corresponding value of the current.

  Note: Remember that you are commanding voltage from the computer; use the parameters s_1 and s_2 identified in the previous labs to determine the voltage-current relationship:

$$i_m(v) = s_1 v + s_2$$

- Calculate the stiction torque using the equation:

$$\tau_{stiction} = \tau_{motor} = i_{m,stiction} * \ \bar{K}, \qquad where\ \bar{K} = k_\tau * \frac{r_{p1}}{r_m}$$

where r_{p1} = 75mm and r_m = 4.3mm (see HapticPaddleSimulink model, Parameters.m, Lab 3A).

- Repeat the previous steps five times, and compute the average static friction torque.
- Redo all the steps above, now commanding a negative current to the motor, to determine the static friction torque in the opposite direction.

b) Identify viscous friction torque

- Calculate the damping B_m at the no-load speed from the datasheet of the Maxon Motor RE25 by using the following equation (**caution: units! ω in rad/s**):

$$i_{m,noload} * k_\tau = B_m * \omega_m$$

- Calculate the damping $\bar{B}$ relative to the paddle axis (hint: B_P=0):

$$\bar{B} = B_p + B_m \cdot \left(\frac{r_{p1}}{r_m}\right)^2$$

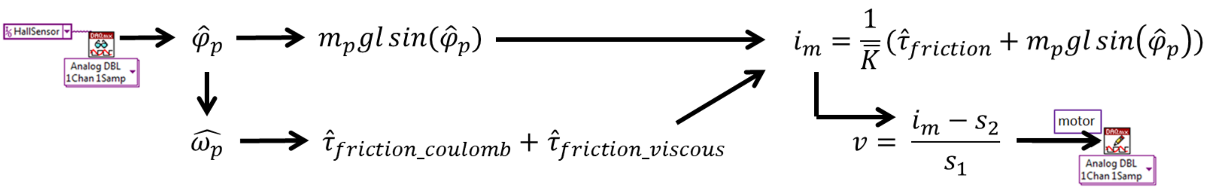
Motor Data			339156
	Values at nominal voltage		
1	Nominal voltage	V	48
2	No load speed	rpm	8450
3	No load current	mA	13.7
4	Nominal speed	rpm	7260
5	Nominal torque (max. continuous torque)	mNm	32
6	Nominal current (max. continuous current)	A	0.608
7	Stall torque	mNm	243
8	Starting current	A	4.51
9	Max. efficiency	%	88.5
	Characteristics		
10	Terminal resistance	Ω	10.6
11	Terminal inductance	mH	1.25
12	Torque constant	mNm / A	53.8
13	Speed constant	rpm / V	177
14	Speed / torque gradient	rpm / mNm	35.1
15	Mechanical time constant	ms	5.12
16	Rotor inertia	gcm²	13.9

2. Coulomb friction, viscous friction, and gravity compensation

a) Build a VI which compensates for the effects of friction and gravity on your Haptic Paddle. In our application with the paddle, it is difficult to compensate for stiction because it would require prior knowledge about when and in which direction the paddle will be moved. **Hence, we will not compensate for stiction, but only for Coulomb friction and viscous friction.** As a simplification, we will assume that the magnitude of Coulomb friction and stiction is similar. Hence, you can use the identified stiction torque values as an approximation to compensate for Coulomb friction.

b) Your loop should be running at 200Hz. Make sure to set the motor output range to *2.0V – 3.0V*.

- A schematic of the required VI is represented here (m_p = 75g, l= 0.0199m):



- Implement a “deadband” (velocity threshold) for the friction compensation, as presented in the lecture. The friction compensation should only kick in when this velocity threshold is overcome. This will increase the robustness of your compensation against, e.g., noise.

- Remember to filter the position signal (particularly important for gravity compensation).

- Compute a velocity estimation of your paddle and filter this signal. Velocity information is essential when compensating for the dynamic (viscous) friction torque.

$$v = \frac{x_k - x_{k-1}}{\Delta T}$$

- You should be able to turn on and off your gravity and friction compensation using two Boolean controls (case structure).
- Implement a waveform chart to monitor the motor voltage, position, and velocity.

c) Test your VI:
Turn on the power and run the VI. Using your Boolean controls, switch both the friction and gravity compensation to OFF. Move the haptic paddle in both directions. You should notice that nothing happens. Turn the switches for friction and gravity compensation ON (one by one or together simultaneously) and observe the difference. Is your controller doing what it is supposed to do? How realistic does it feel? How could we better compensate for friction and gravity?

  - If you are in the lab session:
    Explain this to your assistant, and show your calculated damping coefficient from 1 b). Describe your observations and suggestions for improvement, and the calculated damping coefficients in the lab report.
  - If you are working from remote:
    Describe your observations and suggestions for improvement in the lab report. Report your calculated damping coefficient and hand in a video showing both gravity compensation separately and together with the friction compensation.
    - Gravity compensation: move your paddle to different positions. The paddle should not move back to the 0 position.
    - Friction+gravity compensation ON/OFF: move your paddle with a flexible object (e.g., piece of paper). If the compensation is on, the object should bend less when moving the paddle.