ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

RELAB
REHABILITATION ENGINEERING LAB

Lab 4 B

Goals

- Implement control on the haptic paddle to simulate a virtual wall
- Learn to characterize a haptic device using K-B (stiffness-damping) plots

Required solutions to submit (will be graded)

- K-B plot (report Z-width value; stick to *SI units)*
- Small paragraph answering the questions at the end of point a) and c)
- Show your implemented stable virtual wall to one of the assistants during the next lab

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

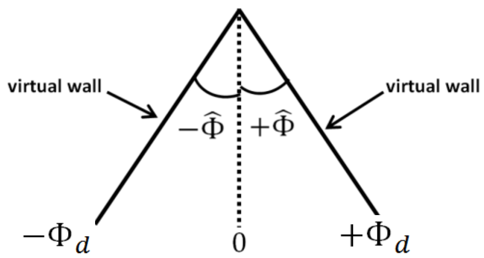
Important Note

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 while loop or timed loop) with a stop button you implement and not with the red stop button in the LabVIEW menu. In the latter case, the program will stop directly, and the "end" part will not be executed.

Implementation of a Virtual Wall on the Haptic Paddle

Note: This exercise requires the LabVIEW VI you developed in the previous lab (Lab 4A). Show your code with friction and gravity compensation to one of the assistants. Please keep your calculated and measured values from Lab 4A ready. You will implement the code for the virtual wall in the same VI (in addition to the existing code from Lab 4A).

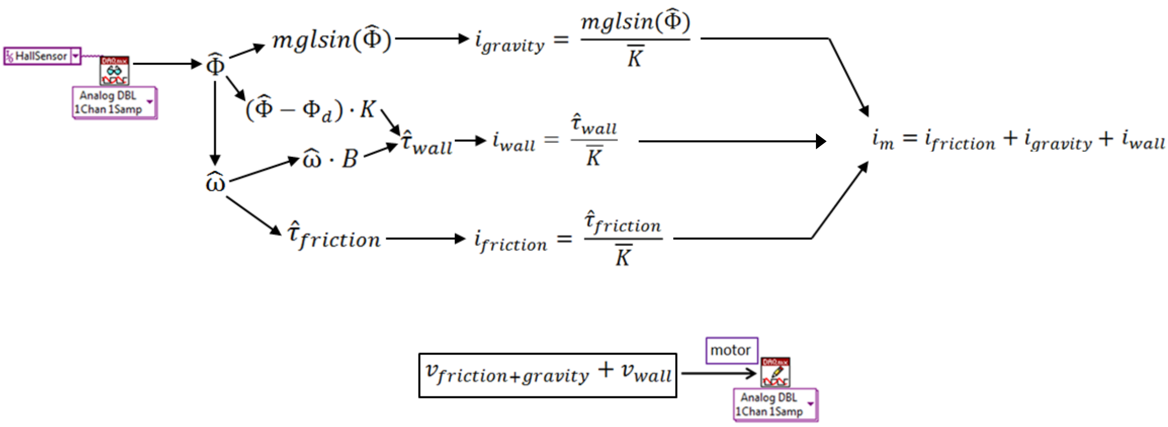
a) Design and implement two virtual walls based on the diagram and relationship below:



$$Wall = (\hat{\Phi} - \Phi_d) \cdot \underbrace{K}_{\text{stiffness}} + \hat{\omega} \cdot \underbrace{B}_{\text{damping}}$$

- Implement two virtual walls (positions at $\Phi_d = \pm 15°$). Include a Boolean control to allow turning your virtual walls on and off.

- As discussed in the lecture, it is crucial to low-pass filter your velocity signal but not your position signal to receive a stable virtual wall (i.e., maximize z-width). **Why is this the case?** Implement a switch (Boolean control) to enable/disable the filters (position, velocity).
- Make sure you select appropriate filter parameters such that you obtain a stable, non-oscillating interaction with the virtual wall.
- A schematic of the required VI is given below:



Note: $\overline{K}$ and K are two different parameters: the former represents the haptic paddle equivalent torque constant, and the latter defines the stiffness of your virtual wall.

b) Determine the Z-width of your haptic paddle (area under the K-B plot), guided by the following steps:

1. Select a very small damping value **B** (start with B=0). Increase the stiffness **K** until the virtual wall becomes/feels unstable (oscillations). Write down the two values (**K** and **B**).
2. Select a very small stiffness value **K** (start with K=0). Increase damping **B** until the virtual wall becomes/feels unstable (oscillations). Write down the two values (**K** and **B**).
3. Repeat step 1) for increasing damping values **B**. You should have at least 5 values of **B** in equal steps from the minimum to the maximum **B** value (from step 2).

- In the end, plot the stiffness (Y-axis) against the damping (X-axis) for your paddle for stable interactions. Plot this for only one side of the paddle ($\Phi_d = +15°$).
- Note: Try always to apply the same interaction force on the paddle when approaching the wall to get consistent results for your K-B plot.

c) Using your Boolean controls, switch both the friction and gravity compensation to OFF and the virtual wall to ON. Move the haptic paddle in both directions and observe the stability when interacting with the virtual wall. Now turn the friction and gravity compensation to ON and repeat the experiment (interacting with the virtual wall). Before you start the experiment, write down your hypotheses about what you expect to observe. Then, perform the experiment and document what you actually observe. Discuss any difference between your hypothesis and experimental data. Is the wall more or less stiff/stable with friction and gravity compensation on? Do you think the wall is sufficiently stiff and stable for applications in pHRI? Could you think of other ways to implement a stiffer (and stable) wall (i.e., achieve a wider Z-width)? What are the tradeoffs here? **Discuss these points in a short paragraph and hand it in along with the K-B plot.**

Remember to keep all the electronic files related to your experiments (data and plots).