ROB 311: HOW TO BUILD ROBOTS AND MAKE THEM MOVE

Professor Rouse, University of Michigan, Fall 2022

Homework 4

Name: ________________________________

Due November 10th at class start (12:00 pm) on Canvas. Create a single PDF that includes concise, clear answers to the questions with plots. Paste your MATLAB / Python code, data, and any other documents as the last pages of your assignment, and together with all your files, upload as a .zip file.

Q1: Due to the alignment of the y-axis and the chassis triad, movement of the ball-bot is more efficient in certain directions—that is, the total motor joule heating loss (i.e. i^2R loss) is a polar function of movement direction. Which movement direction is optimal / which movement direction causes the lowest loss? Provide a *quantitative* justification for your answer.

Q2: You ball-bot has motor torques $T_1, T_2,$ and T_3 that correspond to 1 Nm, 3 Nm, and 4 Nm, respectively. What are the accompanying $T_x, T_y,$ and T_z?

Q3: You're building a gripper to crudely measure force. You plan to use a force sensing resistor (model no: FSR 402, right), and you need to design an analog-to-digital conversion system to do the force measurement. FSRs are resistors whose resistances lower as pressure is applied over the FSR pad. When they're used in combination with a voltage divider, their voltage can be acquired and converted to obtain an estimate of interaction force. Your goal is to design a system that outputs 1 V at 1 kg, which can be sensed through your DAQ system. Your data acquisition system is 16-bit and your voltage range is 0 V – 10 V. The datasheet for your specific FSR (FSR 402) is provided.

Typical force sensing resistor

Design a circuit that enables sensing of the FSR voltage. What other resistance would you choose in the voltage divider? What voltage would you choose for your supply? Label the voltage (node) where you would wire your DAQ system. *Hint:* make sure you see Fig. 1 from the FSR datasheet.

Q4: Define the Nyquist criterion and why it's important. Provide at least one citation to justify your answer.

Q5: This question involves running an experiment with your ball-bot, and you may work with your partner. Together, create a plot / mapping from motor duty cycle to rotational velocity of the chassis. That is, step through the full range of motor duty cycles that make the ball-bot spin about the vertical axis; while doing this, record angular velocity from the IMU and wheel position from the encoders. From these data, determine angular velocity of the chassis using 1) the encoder measurements and 2) the IMU. Perform three tests at each condition to get a feel for the variance in the data. Plot the mean chassis angular velocity as a function of motor duty cycle for your steps, for both the IMU and encoder-based methods. Include error bars that show the standard deviation of the three measurements at each duty cycle (this plot should look like two lines, each with 4-8 points and error bars). How does the calculation of angular velocity compare between the two methods? If they're different, which do you trust more and why?

Q6: Show the decimal, binary, and hexadecimal conversion of the last four digits of anyone's telephone number.

Q7: In binary, what is the full communication message to set the BlinkM LED to fade to hue-saturation-brightness of rich teal at half brightness. To construct the message, specify the address, operational code, and data payload values, each in separate bytes.