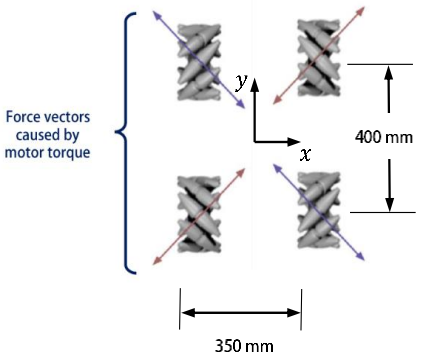
ROB 311: HOW TO BUILD ROBOTS AND MAKE THEM MOVE

Professor Rouse, University of Michigan, Fall 2022

Homework 5

Name: _____

Due December 12th at 12:30 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.

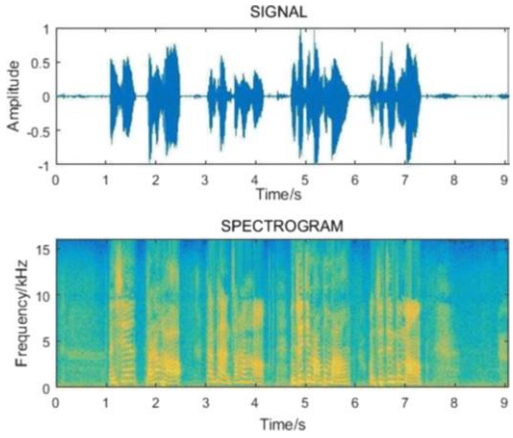


Q1: We learned about Mecanum wheels in class—when they produce torque, the reaction force is canted at a 45° angle (right). a) Describe what Mecanum wheels are used for and b) calculate the four torques required to apply a force 100 N force 30° from the y-axis, while also applying a 5 Nm torque about the center. The wheel radius is 100 mm, the y-axis spacing is 400 mm and the x-axis spacing is 350 mm. This problem is underdetermined—find the combination of wheel torques that have the lowest root mean square.

Q2: Use the HW5Q2.m that was provided on Canvas to answer this question. Tune the PID controller/plant provided, and record your values. Then use the frequency response part of the code to create two plots, both as a function of the sine wave generated in the mfile. That is, you will run this script for multiple frequencies to construct two plots, one that shows the ratio of the input amplitude to output amplitude, and the other showing phase lag, both as a function of sine wave frequency. Describe lag using degrees, where 360° is one full sine wave delayed. Construct the plots for 200 frequencies between 0.1 Hz and 100 Hz, spaced logarithmically.

Q3: Use the data from Q2 to re-construct the plots, but with the following changes:
Magnitude ratio plot: Multiple the ratio by $20\log_{10}(\text{ratio})$, and plot the x-axis (frequency) on a log scale. The y-axis is now log scaled, with units known as Decibels (dB). This type of plot can be created using the `semilog` plot command in MATLAB after converting the function values to dB. *Phase lag plot*: Plot the phase delay with a log (base 10) x-axis (as above). These two plots (log-log magnitude plot and semi-log phase plot) together are known as a Bode Plot.

Q4: A) Any continuous signal can be represented of as the summation of (many) pure sine waves, true or false? B) What is the name for the algorithm that converts a signal to the frequency domain?



Q5: We learned that signals can be analyzed in the time and frequency domains; in fact, a Spectrogram is a plot that shows both domains together. These plots are helpful when needing a deeper understanding of a signal's time-frequency relation. Describe what would change or modify the spectrogram (right) to show the signal band-pass filtered at 2.5 – 10 kHz and notch filtered at 5 kHz. You don't need to be too concerned with exactly how the filters transition.

Q6: This question involves running an experiment with your ball-bot, and you may work with your partner. Together, determine how increasing the chassis inertia affects the bot's ability to balance. You'll need to create a way to increase the inertia by a substantial amount (e.g. 3D print a mount for a 20 oz. soda, tape text books to the top plate, etc.). In addition, you'll need to create a way to add disturbances—this should be a 200 ms repeating torque pulse that increases slightly until the bot tips over (this could be done using time or the PS4 controller or another method). Record the magnitude of the torque pulse that causes the bot to lose balance; run three trials for each inertia value, and do at least three inertia values. Plot your average tipping pulse magnitude vs. approx. added inertia value, and include error bars to show variance. You can choose the direction of the torque pulse.