ME 310 : Microprocessors and Automatic Control Lab

Prasanna Gandhi
Gandhi@iitb.ac.in

Experiment 1: SIMULINK + Concept of feedback in control

Be Ethical, nonethical practices at any point may lead to lowering of your grade

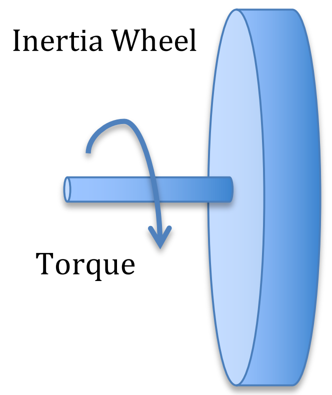
Objectives:

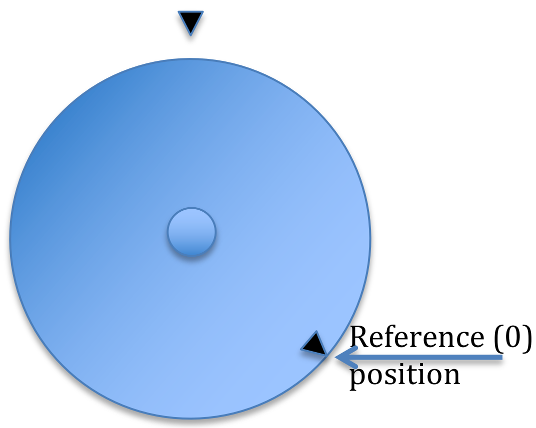
1. Learn to represent linear, constant-coefficient ordinary differential equations as an interconnection of integrators, summing junctions and constant multiplication blocks in SIMULINK.
2. Learn concept of feedback through an example by simulating various cases
3. Be able to interpret simulation results to know what physically it means
4. Explore various control actions and know their effect on a simple system

Background knowledge required:

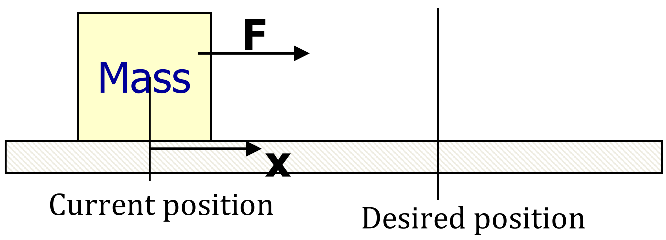
1. Thorough understanding of slides posted if any
2. Familiarity with ordinary differential equations
3. Matlab basics: Go through the basic MATLAB tutorials located at:
   http://www.engin.umich.edu/group/ctm/basic/basic.html and
   http://www.math.ufl.edu/help/matlab-tutorial/
4. Dynamics fundamentals

System under consideration: The cycle wheel on which you can apply torque



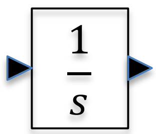


This system is mathematically equivalent (Think why?) to the following system
Point mass resting on a surface:



Things to do:

1. Create a vector x = [-10 -9 .. 0 1 2 ..10] in matlab. Create vectors for the following functions and plot them against x
   a. Y1 = vector of square of each element of x
   b. Y2 = cos(x)
2. Use Newtons law to derive equation of motion of wheel (inertia J) acted upon by torque T(t) rolling in a frictionless bearing as shown in the figure. The torque can be having whatever value we desire it to have. Hence it is 'control input'. The quantity of interest termed as 'output' is rotation angel of wheel. (Think how do you estimate J? given the cycle wheel. Mass of wheel is say 2 kg and radius =0.7 m).
3. Use the equation in 2 to construct SIMULINK block diagram of the system using only integrator (as shown), summation, gain, and multiplication blocks. You will need to open a blank Simulink (.mdl) file and construct the equation. If input to this block is xdot output will be x. You may use sources and sink blocks in SIMULINK. (note that input T is not specified so far)

4. Suppose T is unit step function, simulate system (or find 'response' of system) meaning plot displacement θ as function of time.
5. Suppose torque T = A sin (wt) where frequency w = Sum of digits in your roll number in units of rad/sec and A = 0.1 N, simulate the system in SIMULINK and find out displacement of mass as function of time. Interpret your simulated result in terms of how wheel is going to move under such Torque.
6. **Concept of FEEDBACK:** Now it is desired to have mass move from position zero as shown to position at 120 deg (to match pointer on wheel with vertical pointer) and stay there. Think and come up with one mathematical expression for torque T which will do this job given that you know where you are at the present moment (mathematically this means your torque T would be some function of θ and its first derivative)? (Also since second derivative of θ should not be used as feedback. Mainly because of implementation aspects. Think what they could be!! We will talk about them in later labs)
   With whatever form of T you have constructed, derive equation of error dynamics if error is defined as e = θ_d – θ (θ_d is desired position) and see if the "desired form" of such an equation gives you any hint about the form of T to have error go to zero quickly. (say PD control or so)
   Construct additional blocks / connections in Simulink model to have this expression implemented and simulate how wheel moves with the proposed expression designed by you. (This expression which may use x and/or its derivative and/or integral is called 'control law' which uses 'feedback ' x).
7. Plot the error in matlab and see if it is indeed going to zero. Write down equations of error dynamics under the action of your proposed expression and conclude how the error is going to behave. Plot the input T as function of time and see how it behaves? Is torque zero at time when θ becomes θd??

8. Using expression proposed in 6 for control to further fine tune your parameters such that there are no oscillations in the system and wheel is eventually stationary at the final position.
9. ***Challenge problem:*** All practical systems have friction. We consider simple Coulomb friction with frictional torque = 0.01 Nm. Find and use Coulomb friction block in Simulink to see behavior of your system under same control expression with friction. Does the wheel go to final position? Think what can you do to change your expression for torque such that even with friction wheel goes to the final position. Can this expression work for any wheel and any friction (we should not know actual wheel inertia while implementing control) ? if not can you refine it further… Simulate your system under action of this new modified expression and show how the wheel is moving.