FL. 2018 ESE 447.02 Robotics Lab

Lab Journal 14

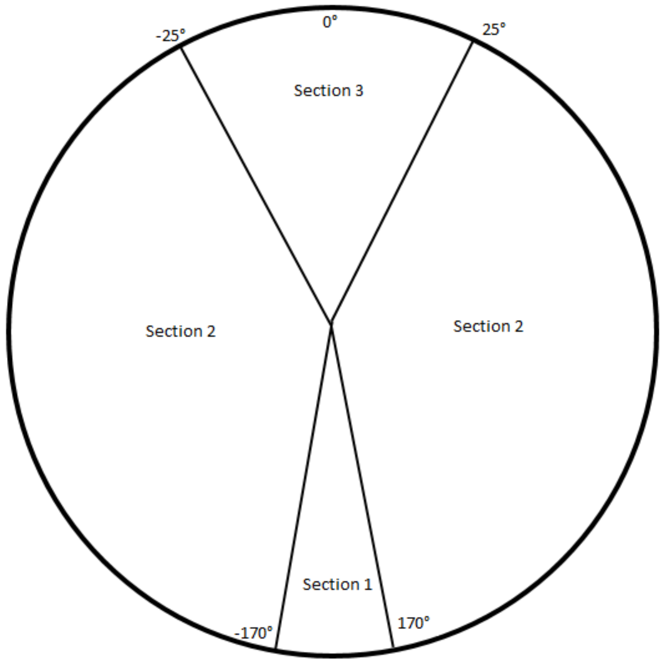
10/31/2018

Starting from this lab, we would be building a Simulink model that could actually control the robot system to make a self-erecting inverted pendulum.
The self-erecting inverted rotary pendulum is a system consisting of one motor and two links jointed with each other. The first link can be motivated by the motor connected on one end and it only rotates in the plane parallel with the ground plane, the second link is connected to the other end of the first link and it can rotates freely with link1 as its axis. The free end of Link2 points to the gravity direction when no stimulation is added.

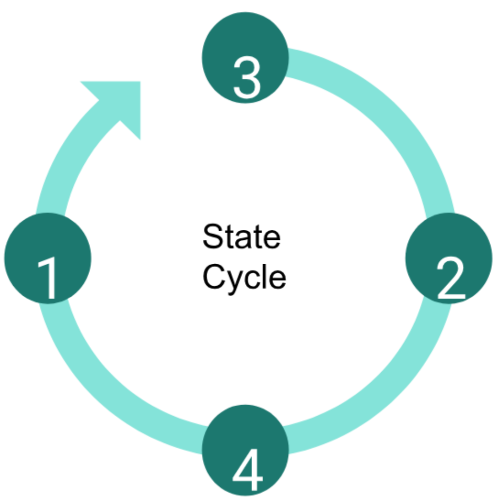
The rotation angle of link1 is noted as q1 and that of link2 is noted as q2. The initial q1 has a value of 0 and initial q2 is 180 degree or pi/2 in radiance.

When proper voltage is provided to the motor, link1 will rotate in a specific pattern and thus cause link2 to swing up. Link 2 will be balanced in a position such that its free end points upwards. At the same time when link2 is in balanced status, link1 can be rotated towards a desired position and the system will balance at the new position. When the system is out of balance due to external disturbance or relatively strong q1 inputs, link1 will go back to its initial position before the swing-up, and then the system will repeat the swing-up and balance process.

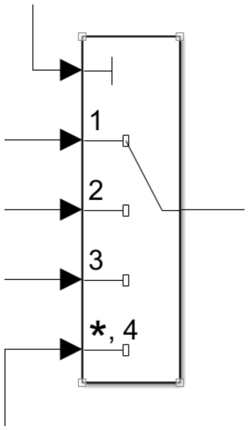
1. Division of regions for link2 rotation area.
   As a preparation before modeling the system in Simulink, we decided that the round area in which link2 can rotate can be divided into 3 regions. Region1 is where link2 is supposed to swing up, region3 is where link2 should balance and region2 is all other regions where we wait till link2 to calm down.
   The size of region1 is ±10 degrees around the lowest position, the size of region3 is ±25 degrees around the highest position. It is important to note that the lowest position of link2 has q2 of 180 degrees or pi/2 radiance.
   Besides, the value of q can go to infinite if it keeps spinning, so we need to normalize q2 to fit the q2 value into different regions. The method we used to normalize q2 was using the trig functions in Matlab. We took the arctangent of the division of sinq2 and cos q2, and this yielded a normalized interval between negative pi and positive pi. So our region can be graphed as shown below.



Region1 is where link2 is supposed to swing up, region3 is where link2 should balance and region2 is all other regions where we wait till link2 to settle down.
The size of region1 is ±10 degrees around the lowest position, the size of region3 is ±25 degrees around the highest position. The system recognizes the 0 zero position in the same way shown in the picture.
We applied a certain sequence in which the states switch so that the states only cycles in the order 4-1-3-2-4. In the following steps I would cover what the 4 states mean.



2. Selector function for different input needs.
The selector is a function that can switch among different input signals so that desired input for different controllers can be activated in different conditions. A multi-switch block was used in the Simulink model.



This block allows the switch between the input ports listed from 1 to 4 for our case. More posts could be added if needed. The top port unlabeled is the control input port through where a number from 1 to 4 that correspond to the signal ports can be fed, thus switching between the signal ports. Therefore what our selector function did was basically stating different conditions we need and output numbers from 1 to 4 based on different conditions.

The first condition was for the swing-up. When link2 is in region 1 and the speed of q2 is close to 0, and the previous state was 4, then current the state is defined as state1, and the selector will output 1 to the multi-switch block.

The second condition was for the settling down. When link2 is in region 2 and the speed of link2 is greater than 0, and the previous state was 3, then this state was defined as sate 2.

The third condition was for balancing link 2. When link2 is in region 3 and its previous state was 1, the state is defined as state 3.

The fourth state was for link 1 to go back to its position before swinging up so that the system can start swinging up at the same initial position every time. When link1 has a rotation angle greater than 0 and the speed of link 2 is small enough, and the previous state was 2, the current state is then defined as state 4.