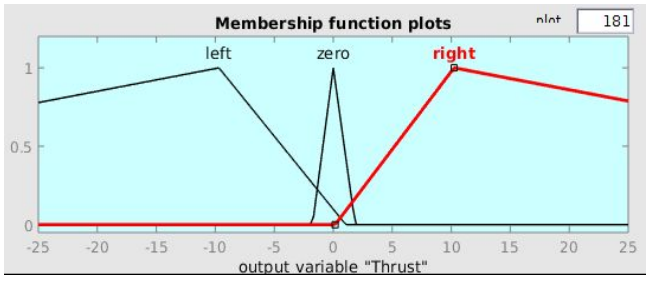
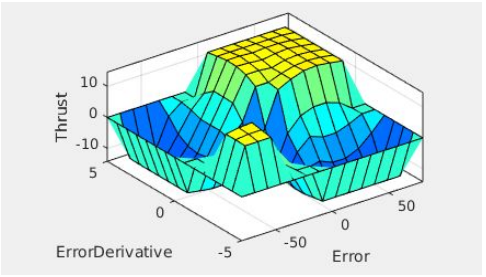
Laboratory exercise 1: FUZZY SYSTEMS

1) Description of the membership functions that you have designed for the output variable and the rule base defined. Argue why you have chosen these membership and rules.

Membership functions for output variable





The memberships functions were chosen for the following reasons:

- Three actions were needed for each pendulum's position.
- The Thrust left action was in charge to apply a force to the left with a magnitude = [-25, 0] being the intensity stronger from -25 to -10 in order to accelerate the correction of the angle.
- The Thrust left action was in charge to apply a force to the right with a magnitude = [0, 25] being the intensity stronger from 10 to -25 in order to accelerate the correction of the angle.
- The Thrust zero action was in charge to apply a little bit force when the pendulum is close to the desired angle.

Rule base

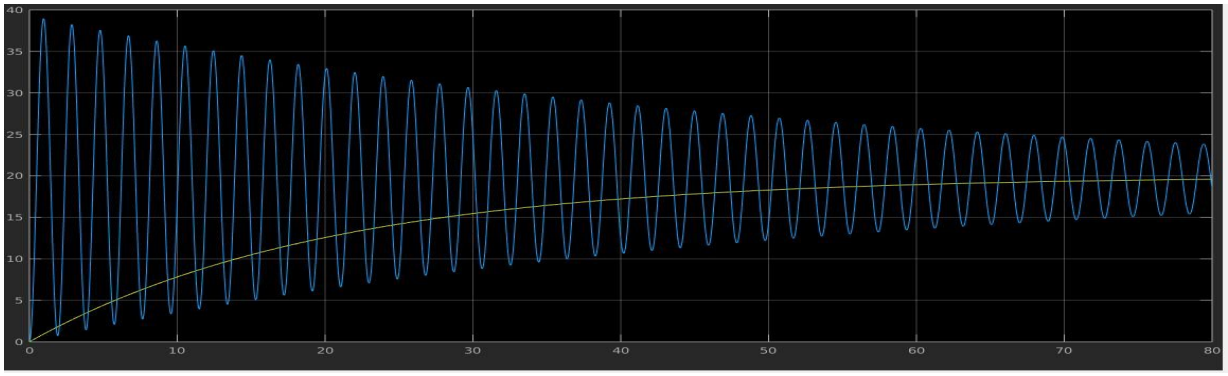
1. If (Error is Negative) and (ErrorDerivative is Decrease) then (Thrust is right) (1)
2. If (Error is Negative) and (ErrorDerivative is Stationary) then (Thrust is left) (1)
3. If (Error is Negative) and (ErrorDerivative is Increasing) then (Thrust is left) (1)
4. If (Error is Zero) and (ErrorDerivative is Decrease) then (Thrust is left) (1)
5. If (Error is Zero) and (ErrorDerivative is Stationary) then (Thrust is zero) (1)
6. If (Error is Zero) and (ErrorDerivative is Increasing) then (Thrust is right) (1)
7. If (Error is Positive) and (ErrorDerivative is Decrease) then (Thrust is left) (1)
8. If (Error is Positive) and (ErrorDerivative is Stationary) then (Thrust is right) (1)
9. If (Error is Positive) and (ErrorDerivative is Increasing) then (Thrust is right) (1)

The idea behind the rule base is to try to stabilize the pendulum considering its position. For instance:

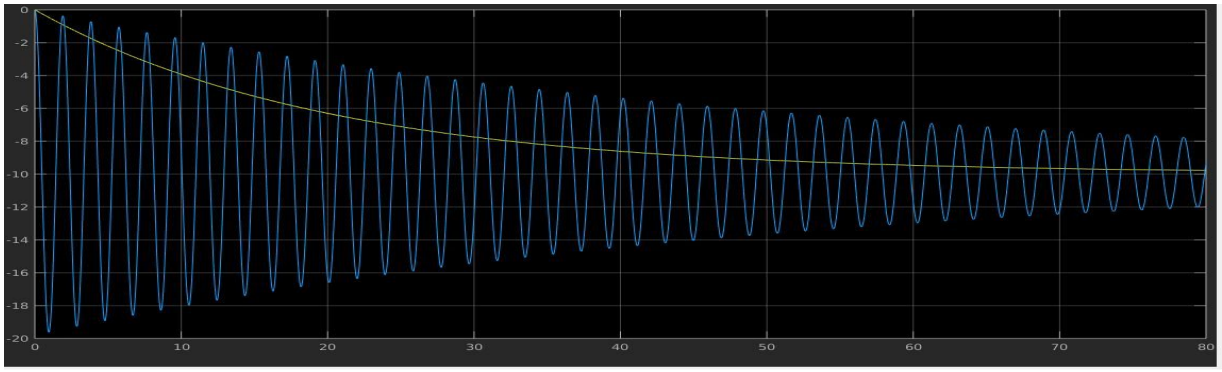
- (Error is Negative) and (ErrorDerivate is Decrease), it means that the pendulum is on the right side of the desired position but the direction is going left. That's why a force to the right direction is needed to stabilize it.
- (Error is Positive) and (ErrorDerivate is Decrease), it means that the pendulum is on the left side of the desired position but the direction is going right (approaching the desired position). So a force to the left direction is need to reduce the pendulum speed.
- (Error is Zero) and (ErrorDerivate is Stationary), it means don't do anything, so the force applied is close to zero.

2) Plots of the results that you get for the following values with a simulation stop time of 80:
2.1) theta_ref = 20 and thrust = 0.123
2.2) theta_ref = -10 and thrust = -0.062
Write your own comments about the results that you get.

theta_ref = 20 and thrust = 0.123



theta_ref = -10 and thrust = -0.062



The system is trying to approach to the desired angle (20, -10) given the Trust (0.123, -0.062), the behaviour is as expected. As for one side, the pendulum is reducing its amplitude due to the fuzzy control. The same for the second result, the fuzzy control helps to reduce the speed and approach the -10 angle. However, it takes some time to stabilize. Perhaps, a different type of function (gaussian, trapezoidal, etc) can help to boost the fuzzy control.

3) What happens if you increase the number of membership functions of the output?

Adding more memberships functions can help to be more precise when applying a force. Perhaps, having 1 function between LEFT and ZERO, called SOFT_LEFT, and another between ZERO and RIGHT, called SOFT_RIGHT, could help to apply an accurate force to a particular position. To sum up, the more functions, the more level of granularity.