CO542 – Neural Networks and Fuzzy Systems
Lab 2 – Fuzzy Logic

Note: You may need to complete Lab 1 first to be familiar with the concepts and MatLab environment.

Scenario – Two Inputs One Output

Suppose you are assigned to design a fuzzy control system to determine the force needed to balance an inverted pendulum in a cart. Consider the inputs and output as given below. The angle (θ) between the platform and the pendulum and the angular velocity (ω) of this angle are chosen as the inputs of the system. The Force (F) to be applied on the platform to balance the pendulum is chosen as the corresponding output.

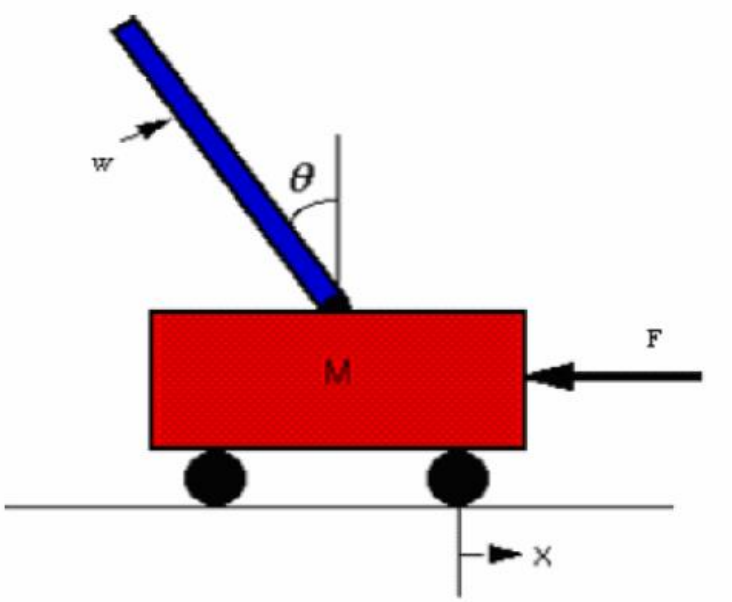

Figure 1: Inverted Pendulum in a cart

Input 1 : Angle (θ)
States of Input1 : (NH, NL, Z, PL, PH)

Input 2 : Angular Velocity (ω)
States of Input2 : (NH, NL, Z, PL, PH)

Output :
Force to be exerted to cart (F)

NH – Negative High (-2)
NL – Negative Low (-1)
Z – Zero (0)
PL – Positive Low (1)
PH – Positive High (2)

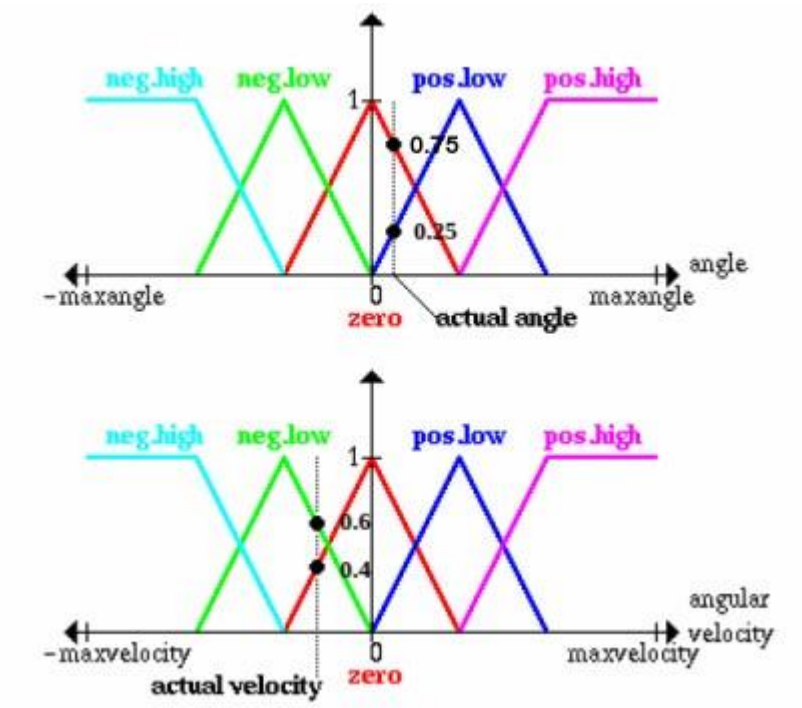

Figure 2: Membership for angle and angular velocity

Lab Tasks

1. Define all the Fuzzy rules for the Scenario.
   - Hint: Use below table to identify each rule

		Angle (θ)				
		NH	NL	Z	PL	PH
Angular Velocity (ω)	NH					
	NL					
	Z					
	PL					
	PH					

2. The membership values used for this part are 0.75 and 0.25 for zero and positive-low angles, and 0.4 and 0.6 for zero and negative-low angular velocities (Figure 2). Calculate the Force (F) that needed to be exerted on the cart.
   - Step 1: Identify the relevant rules for this case
   - Step 2: Calculate the membership function value (μ_{ij}) relevant to each fuzzy output (e.g. Force)
     - Hint : Use algebraic product
     - Illustrate each μ_{ij} with a help of figure (Two input membership functions vs one output membership function)
   - Step 3: The result of the fuzzy controller as of now is a fuzzy set (of force). In order to choose an appropriate representative value as the final output (crisp values), defuzzification must be done. There are numerous defuzzification methods, but the most common one used is the

"Centroid Defuzzification" as shown below. Substitute them and find out F force (using the centroid defuzzification method).

$$f(x) = \frac{\sum_{i=1}^{N} z^i \prod_{j=1}^{n} \mu_{ij}(x_j)}{\sum_{i=1}^{N} \prod_{j=1}^{n} \mu_{ij}(x_j)}$$

Where "z" is fuzzy output and "μ_{ij}" is the relevent membership function value. "Σ" denotes the summation and "Π" denotes the crisp product.

3. Solve the same using Fuzzy Logic tool box in Matlab and verify the answers you got from your calculations and the answer you get from MATLAB.
   - Commnads: (Save the file as "Inverted_Pendulum.fis")
     - » fis = readfis(' Inverted_Pendulum');
     - » out=evalfis([65 -0.1],fis)
     - » surfview(fis) [gives the output surface of the fuzzy system]

Hint:

Use the following configuration parameters in FIS for your Lab Tasks

- Controller Type : Mamdani
- Defuzzification Method : Centroid
- And : Min
- Or : Max
- Implication : Min
- Aggregation : Max

Some other useful commands

- readfis(), evalfis(), surfview()

Note: You have to submit Matlab files along with snapshots of each below.

- Input Membership Function
- Graphical Calculation of each "μ_{ij}"
- Output Membership Function
- Rule Base
- Surface Map

Submission

You can submit a single ZIP file as e15XXXlab02.zip including all:

- A PDF file with rule base, tables, numerical calculations, graphical calculations, results, and snapshots of Matlab simulation as indicated in the labs, any descriptions, etc.
- MatLab Files

~ All images (graphical calculations and outputs from MatLab)

Note: XXX indicates your registration number in all cases. **Those who have plagiarized content will be heavily penalized.**