M.TECH. INTELLIGENT AUTOMATION AND ROBOTICS SECOND YEAR SECOND SEMESTER - 2018

Subject: **FUZZY CONTROL SYSTEM** Time: 3 Hours Full Marks: 100

Answer any FOUR.

All parts of the same question must be answered at one place only

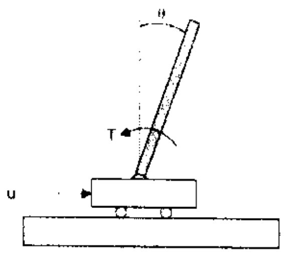
1. While designing CMOS inverter circuit, it is observed that the W/L ratio of both n-MOS and p-MOS must increase proportionally with an increase in the output load capacitance to maintain the same delay time.
   (a) Design a suitable production rule to capture the design objective.
   (b) Find a fuzzy relation for the proposed rule using
   $$\mu_{\text{LARGE}}(\textit{capacitance}) = \{0.36|0.5 \text{ pF}, 0.57|2 \text{ pF}, 0.98|8 \text{ pF}\} \text{ and}$$
   $$\mu_{\text{HIGH}}(W/L) = \{0.14|4, 0.82|16, 0.95|64\}.$$
   (c) Plot the three-dimensional view of the relational matrix obtained in (b).
   (d) Find out the fuzzy membership distribution of W/L ratio if the designer is interested with VERY HIGH load capacitance.
   (e) Graphically verify the result obtained in (d) using the three-dimensional representation of the relational matrix obtained in (c).

1+4+5+4+11=25

2. The force to be applied to an aircraft while descending is controlled by its altitude and downward velocity. The applied force must ensure that the aircraft will descend promptly from high altitude but will touch the ground very gently to avoid damage. The dynamics of the system is given by
   $$v(t+1) = v(t) + F(t) \text{ and } h(t+1) = h(t) + v(t),$$
   where the downward velocity $v(t) \in [-30 \text{ ft/s}, 30 \text{ ft/s}]$, the altitude $h(t) \in [0 \text{ ft}, 1000 \text{ ft}]$ and the exerted force $f(t) \in [-30 \text{ lbs}, 30 \text{ lbs}]$ and t is the time instant.
   (a) Define membership distributions of the state variables and the control output.
   (b) Design the production rules satisfying the desired objective of aircraft landing.
   (c) From the designed membership distributions and proposed production rules, determine $F(0)$, $v(1)$ and $h(1)$ for $v(0) = -20$ ft/s and $h(0) = 1000$ ft.

7+8+10=25

3. The linear differential equation of an inverted pendulum is given below.



$$\frac{4l}{3}\frac{4M+m}{4m}\ddot{\theta} - \frac{M+m}{m} g\theta = -\frac{u}{m}\frac{180}{\pi}$$
$$\text{with } l = \frac{3(M+m)g}{4M+m} \text{ and } M = \frac{180}{\pi g} - m$$

where m is the mass of the pole assumed to be concentrated at the center of the pendulum

M is mass of the cart

$2l$ is the length of the pendulum

θ is the deviation angle from vertical in the clockwise direction

T is the torque applied to the pole in the counterclockwise direction

u is the control on the cart acting from left to the right producing the counterclockwise torque T

t is time, and

g is the gravitational acceleration constant

(a) Define membership distributions of the state variables and the control output for $\theta(t) \in [-2$ degree, 2 degree], $\dot{\theta}(t) \in [-4$ dps, 4 dps] and $u(t) \in [-10, 10]$.

(b) Design the production rules for balancing the inverted pendulum in the vertical position.

(c) From the designed membership distributions and proposed production rules, determine $u(0)$, $\theta(1)$ and $\dot{\theta}(1)$ for $\theta(0)$= 1 degree and $\dot{\theta}(0) = 0$ dps.

7+8+10=25

4.(a) State the Lyapunov stability criteria for a Takagi-Sugeno fuzzy control system with n production rules.

(b) Comment on the stability of a Takagi-Sugeno fuzzy control system with two production rules, described by the following system matrices.

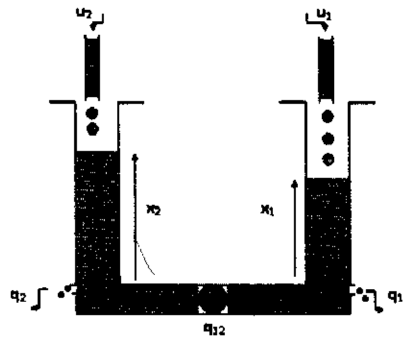
$$A_1 = \begin{bmatrix} 1 & 0.2 \\ -0.3 & 0.5 \end{bmatrix} \text{ and } A_2 = \begin{bmatrix} 0.5 & 0.12 \\ -0.18 & 0.2 \end{bmatrix}.$$

6+19=25

5.(a) Define Takagi-Sugeno fuzzy control system.

(b) Explain the advantage of Takagi-Sugeno fuzzy control over Mamdani fuzzy control system.

(c) Design suitable fuzzy control system architecture of the following two-link tank system using Takagi-Sugeno model.



(d) Briefly explain different defuzzification methods with suitable examples.

6+3+10+6=25

6.(a) Explain the Kernik-Mendel algorithm for type-2 defuzzification.

(b) Design a type-2 fuzzy control system for a robot navigating an uncertain environment, preferrebly steering in clockwise direction. Capture the uncertainty in the membership distribution of its steering angle when the range data measured by the front right and the back right sensors are respectively given by 170 cm and 240 cm.

10+15=25