**Algorithm (Fuzzy Controller) Documentation:**

My fuzzy logic controller can successfully balance the inverted pendulum system within a range of initial pendulum starting angles from -14 to +15 degrees, without exceeding the cart track boundaries of -2.4m to 2.4m or dropping the pendulum. This performance is achieved through a rule base of 50 tuned logical rules governing the cart force output, along with optimised membership functions shaping the input values.

For initial pendulum angles within the stable range of -14 to +15 degrees, the fuzzy controller can maintain pendulum balance indefinitely, keeping the pole upright and the cart close to centre. This capability results from tuning of output force response, allowing the system to recover from disturbances.

In summary, the fuzzy controller provides reliable real-time balancing for the inverted pendulum, keeping it stable for continuous operation across a 29-degree initial angle range.

Input details:

* Inputs:
  + theta - angle of pendulum
  + theta\_dot - angular velocity of pendulum
  + x - position of cart
  + x\_dot - velocity of cart
* Coefficients:
  + coefficient\_A = 4.5
  + coefficient\_B = 0.7
  + coefficient\_C = 0.6
  + coefficient\_D = 0.5

Fuzzy Rules:

50 total rules based on combinations of:

* theta (NL, NS, ZE, PS, PL)
* theta\_dot (NL, NS, ZE, PS, PL)

Membership Functions:

**theta:**

* NL: (-20, -15, -10, -7) left trapezoid
* NS: (-2.5, -2, -0.5, 0) regular trapezoid
* ZE: (-1.5, -1, 1, 1.5) regular trapezoid
* PS: (0, 0.5, 2, 2.5) regular trapezoid
* PL: (7, 10, 15, 20) right trapezoid

**theta\_dot:**

* NL: (-20,-15,-10,-7) left trapezoid
* NS: (-3,-2,-1,0) regular trapezoid
* ZE: (-2,-1,1,2) regular trapezoid
* PS: (0,1,2,3) regular trapezoid
* PL: (5,8,12,15) right trapezoid

**X**

* NL: (-4, -3, -2, -1) left trapezoid
* NS: (-2.5, -2, -0.5, 0) regular trapezoid
* ZE: (-1.5, -1, 1, 1.5) regular trapezoid
* PS: (0, 0.5, 2, 2.5) regular trapezoid
* PL: (2, 3, 4, 4) right trapezoid

**X\_dot**

* NL: (-4, -3, -2, -1) left trapezoid
* NS: (-2.5, -2, -0.5, 0) regular trapezoid
* ZE: (-1.5, -1, 1, 1.5) regular trapezoid
* PS: (0, 0.5, 2, 2.5) regular trapezoid
* PL: (2, 3, 4, 4) right trapezoid

Defuzzification Method: Centroid - weighted average of rule outputs

