Neurofuzzy Control and Applications
Electric Train Fuzzy Controller

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1 Introduction

The purpose of this exercise is to construct a fuzzy controller for an electric rail system. Given the mathematical modeling of our system, we build our controller using fuzzy and PID techniques.

2 Math Model

The differential equation of the train is as follows:

$$m \cdot \frac{\mathrm{d}^2 x}{\mathrm{d}t^2} = -(a_1 + m \cdot a_2) \cdot \dot{x} - a_3 \cdot \dot{x} \cdot |\dot{x}| + b \cdot u \tag{1}$$

,where x is the train's position, m it's mass, a_1, a_2, a_3 friction parameters and bu represents the acceleration or deceleration due to the use of the electric motor.

We also consider the following nominal values: $m = 100$, $a1 = 1$, $a2 = 0.05$, $a3 = 0.1$ and $b = 200$.

3 Specifications

Our fuzzy controller must meet the following specifications:

1. Between stations the train develops a reference speed.
2. Must reach its destination quickly and without elevating.
3. The entry satisfies $u \in [-1, 1]$.

4 Demands

4.1

The fuzzy controller was designed with Mamdani type rules to meet the above specifications.

Below we see the design of the controller as a whole.

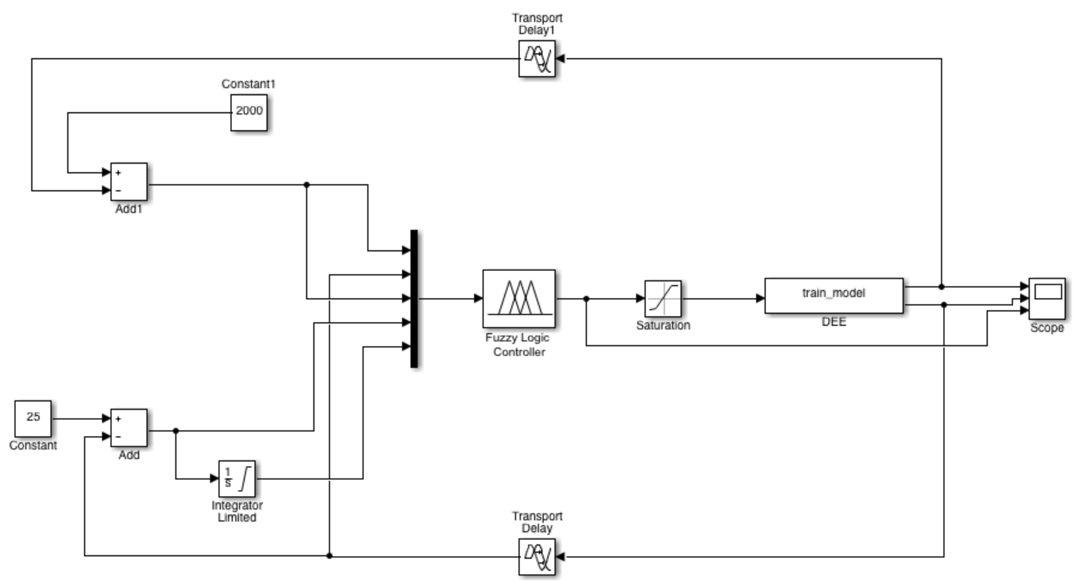

Figure 1: Fuzzy train controller.

The inputs to the system are the desired position $x = 2000$ and the initial speed $\dot{x} = 25$. Because the inputs of the Fuzzy Logic Controller are position and speed errors, we can say that we also make use of PID techniques. The DEE block is a means of introducing differential equations and contains the mathematical model of the train. As the outputs of the system we take the position (x) and the speed ($\dot{x}$).

As shown in the figure, the inputs of the multiplexer and then of the fuzzy controller, are:

1. Position error
2. Speed

3. How far or close from the target
4. Speed error
5. Speed integral, which is the position

By defining the rules correctly and choosing the right membership functions, we notice that our controller provides the correct results, ie the above specifications are observed.(2)

4.2

Our system depends to a large extent on the rules and membership functions. Any change in the parameters will change the behavior of the system depending on, for example, its position or its speed. The graphs **??** are the result of tweaking the parameters to meet the required specifications.

4.3

In this case we assume that the train is on an inclined plane. Now it accepts another external force due to the inclination. This is the parallel to the inclined plane component of its weight. That is, the differential equation modeled by the new system is:

$$m \cdot \frac{\mathrm{d}^2 x}{\mathrm{d}t^2} = -(a_1 + m \cdot a_2) \cdot \dot{x} - a_3 \cdot \dot{x} \cdot |\dot{x}| - m \cdot g \cdot \sin\theta + b \cdot u \tag{2}$$

,where $mgsin(\theta)$ is that force, with $g = 10m^2/s$ the acceleration's gravity and θ the angle of the inclined plane. Also, $m = 90$. We can observe that every moment is valid:

$$\theta = \frac{h}{x} \tag{3}$$

,with h the height of the incline, from it's highest point to the ground. So 2 can be written:

$$m \cdot \frac{\mathrm{d}^2 x}{\mathrm{d}t^2} = -(a_1 + m \cdot a_2) \cdot \dot{x} - a_3 \cdot \dot{x} \cdot |\dot{x}| - m \cdot g \cdot \frac{h}{x} + b \cdot u \tag{4}$$

This nonlinearity factor $\frac{h}{x}$ makes it very difficult to resolve the differential, with the result that this controller does not meet the specifications.

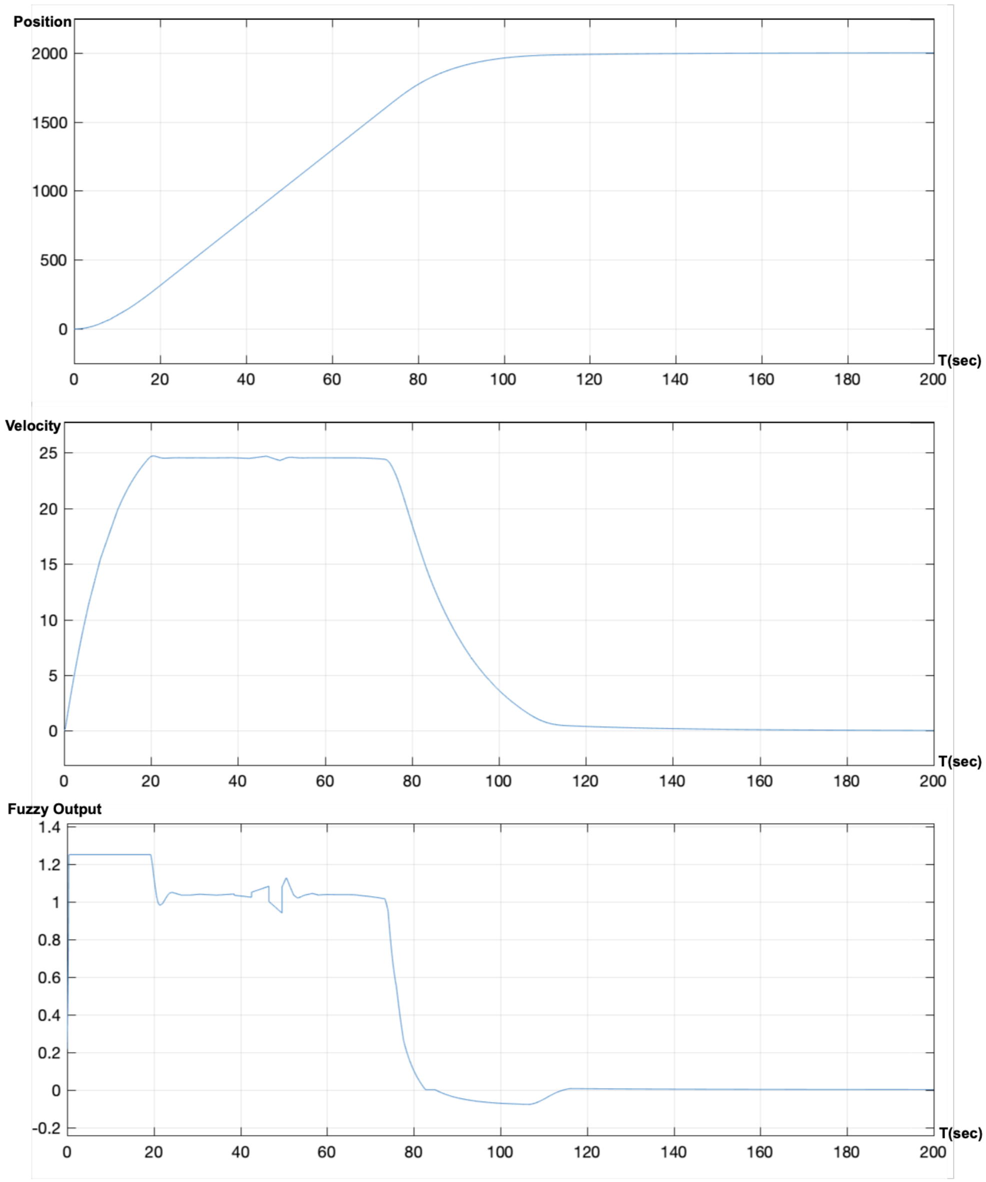

Figure 2: System's plots.