

Speed Control of a Train using Fuzzy Logic

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Abstract: The prime motive of this paper is to show how to control the speed of a train using Fuzzy Logic controller. The fuzzy knowledge can be used to enhance the performance and credibility of the conventional controller. Here, we are going to use the atmospheric conditions and the distance to be covered as the input to the fuzzy controller. The optical fog sensor will measure the amount of water particles i.e. fog in the air that limits the visibility and GPS can be used to measure the distance. When these two inputs are given to Fuzzy Knowledge based controller, they are processed according to the inference rules and speed of the train is obtained as output. The advantage of using fuzzy logic is that the higher degree of automation can be achieved, resulting in consistent control around the clock.

Keywords: Fuzzy logic controller, intelligent train, visibility, speed

1. Introduction

Railways are the most common means of transport in South Asia. It is widely used for day to day travel and for transporting goods over entire length and width across the country. With the heavily busy routes all over, it is high time to make way for intelligent trains which can take decision by itself in the complex working environment. The Indian subcontinent witnesses all types of weather which includes summer, winter, monsoon and autumn season. The train transport facilities have to be available throughout the year as it is the backbone of the country. There are several ways to automatically control the speed of train. One such method is using Fuzzy Logic Controller which can be used solely or as an extension of conventional controller for the speed control. The fuzzy method is easy to learn and useful in the case of conflicts and disturbance. The knowledge and experiential rules of a train driver can be incorporated in the fuzzy logic controller to control the speed of the train precisely. This reduces the need of continuous attention of train personnel. The fuzzy controller intakes the input parameters i.e. distance and visibility yielding the output i.e. appropriate speed after processing the crisp data(input) according to the rule base.

2. Speed Controller Model

This controller uses two input variables which are as follows:

- 1) Distance
- 2) Visibility

The block diagram of the fuzzy speed controller is shown as below. From the diagram, we can observe that the controller takes two inputs, process it and speed is given as the output. As discussed earlier, the inputs distance and visibility is fed to the controller using the corresponding sensors. The controller will analyze the inputs from the sensors and the speed of the train can be changed accordingly. The process involves fuzzifying the crisp data, process it and then give the defuzzified value of the output(speed).

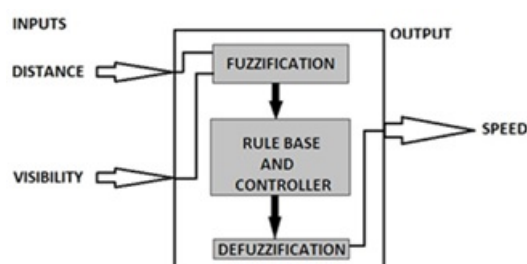


Figure 1: Block Representation

3. Design Constraints

To design Fuzzy speed controller following assumptions are made:

- 1) Consider a train moving from point A to point B as shown in the figure 2.
- 2) There is no obstruction on the tracks.



Figure 2: Train moving from A to B

4. Controller Design

To make the controller work, the range of possible values of inputs i.e. distance and visibility as well as the range of possible values of output i.e. speed is determined. In fuzzy language, these set of variables are membership functions which is used to map the crisp values to the fuzzy values. This will enable the fuzzy engine to process the inputs according to the defined inference rules. The set of membership values for the corresponding fuzzy functions are tabulated in Fuzzy Associative Matrix (FAM).

4.1 Inputs

4.1.1 Distance

The range for the above membership function is taken from 0 km to 100 km. The membership values are defined with the

help of linguistic variables. The linguistic variables chosen are: very short(VS), short(S), medium(M), long(L), very long(VL).

Table 1: FAM (Distance)

	Distance(Km)										
	0	10	20	30	40	50	60	70	80	90	100
VS	1	0.3	0	0	0	0	0	0	0	0	0
S	0.5	0.6	0.8	1	0.6	0.3	0	0	0	0	0
M	0	0	0	0.3	0.6	1	0.6	0.3	0	0	0
L	0	0	0	0.1	0.3	0.5	0.75	1	0.8	0.55	0.3
VL	0	0	0	0	0	0.2	0.3	0.5	0.7	0.85	1

The representation of the membership function “Distance” is given below.

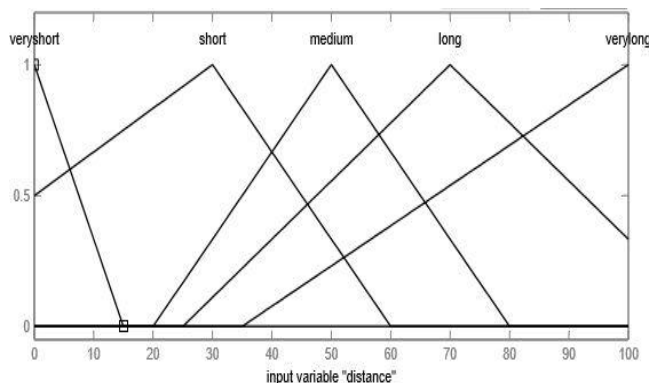


Figure 3: Membership Function (Distance)

4.1.2 Visibility

The range for the above membership function is defined on the scale of 0 to 10. The maximum value 10 being the clear visibility and minimum value 0 be the hazy visibility. The linguistic variables chosen are: Hazy, Moderate, Clear.

Table 2: FAM (Visibility)

	Visibility										
	0	1	2	3	4	5	6	7	8	9	10
Hazy	1	0.75	0.5	0.25	0	0	0	0	0	0	0
Moderate	0	0	0.25	0.5	0.75	1	0.75	0.5	0.25	0	0
Clear	0	0	0	0	0	0	0	0.25	0.5	0.75	1

The representation of the membership function “Visibility” is given below.

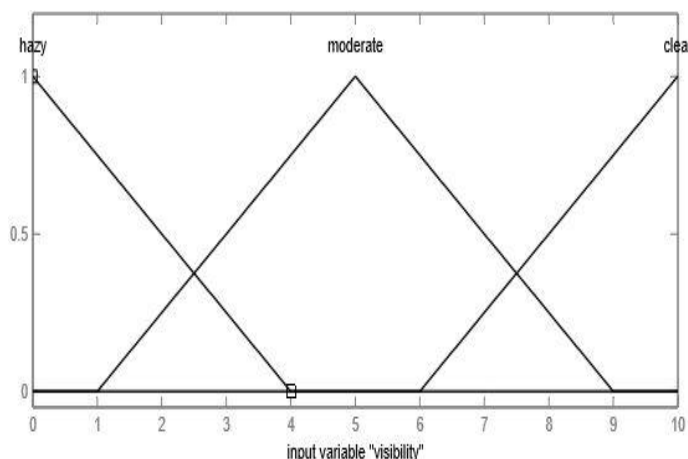


Figure 4: Membership Function (Visibility)

4.2 Output

1) Speed

The range for the above membership function is taken from 0 km/hr to 120 km/hr. The linguistic variable chosen are: Very Slow(VS), Slow(S), Medium(M), High(H), and Very High(VH).

The FAM of the output is shown in table 3 below:

Table 3: FAM (Speed)

	SPEED(KM/HR)												
	0	10	20	30	40	50	60	70	80	90	100	110	120
VS	1	0.6	0.2	0	0	0	0	0	0	0	0	0	0
S	0	0.3	0.6	1	0.5	0	0	0	0	0	0	0	0
M	0	0	0	0	0.3	0.6	1	0.6	0.3	0	0	0	0
H	0	0	0	0	0	0	0	0.3	0.6	1	0.6	0.3	0
VH	0	0	0	0	0	0	0	0	0	0.75	0.5	0.75	1

The representation of the membership function “Speed” is given below.

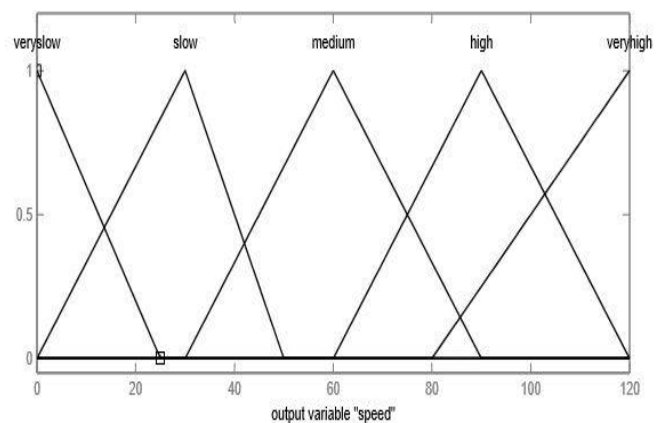


Figure 4: Membership Function (Speed)

4.3 Rule Base

The decision which the fuzzy controller makes is derived from the rules which are stored in the database. Basically, the rules are if-then statements which are easy to understand. The if-part of such a rule is called rule-antecedent and then-part of the rule is called the rule-consequent. The set of rules used to derive the output are:

- If (distance is veryshort) and (visibility is hazy) then (speed is veryslow)
- If (distance is veryshort) and (visibility is moderate) then (speed is veryslow)
- If (distance is veryshort) and (visibility is clear) then (speed is slow)
- If (distance is short) and (visibility is hazy) then (speed is veryslow)
- If (distance is short) and (visibility is moderate) then (speed is slow)
- If (distance is short) and (visibility is clear) then (speed is medium)
- If (distance is medium) and (visibility is hazy) then (speed is veryslow)

- h) If (distance is medium) and (visibility is moderate) then (speed is medium)
- i) If (distance is medium) and (visibility is clear) then (speed is high)
- j) If (distance is long) and (visibility is hazy) then (speed is veryslow)
- k) If (distance is long) and (visibility is moderate) then (speed is medium)
- l) If (distance is long) and (visibility is clear) then (speed is veryhigh)
- m) If (distance is verylong) and (visibility is hazy) then (speed is veryslow)
- n) If (distance is verylong) and (visibility is moderate) then (speed is high)
- o) If (distance is verylong) and (visibility is clear) then (speed is veryhigh)

5. Simulation Results

Using FIS Editor GUI tool in MATLAB, a simulation experiment was carried out to evaluate the feasibility of the fuzzy logic speed controller. The FIS editor allows editing the fuzzy inference system features such as number of input and output variables, Defuzzification method etc. The below figures describe the simulation:

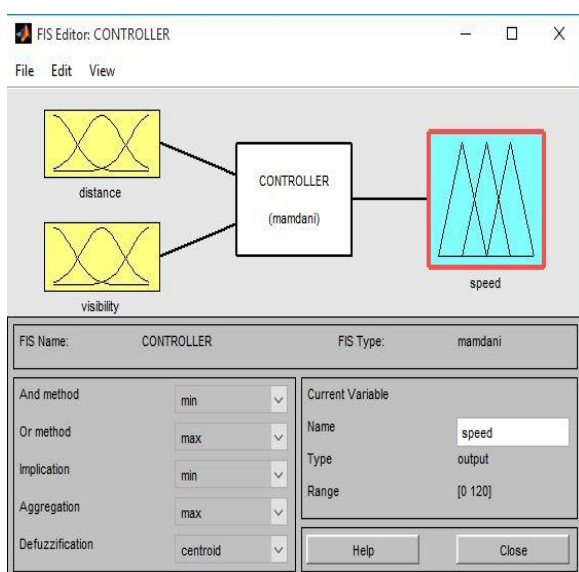


Figure 5: FIS Editor

The rule viewer: Here we can give different inputs (distance & visibility) and we can see simulated output (speed). The output of the controller i.e. speed was changing as the inputs were varied.

Example:

When distance to be covered is 50 km and visibility is 5 i.e. moderate then the simulated speed of the train is 57.6 km/hr. The following result can be seen in the figure given below.

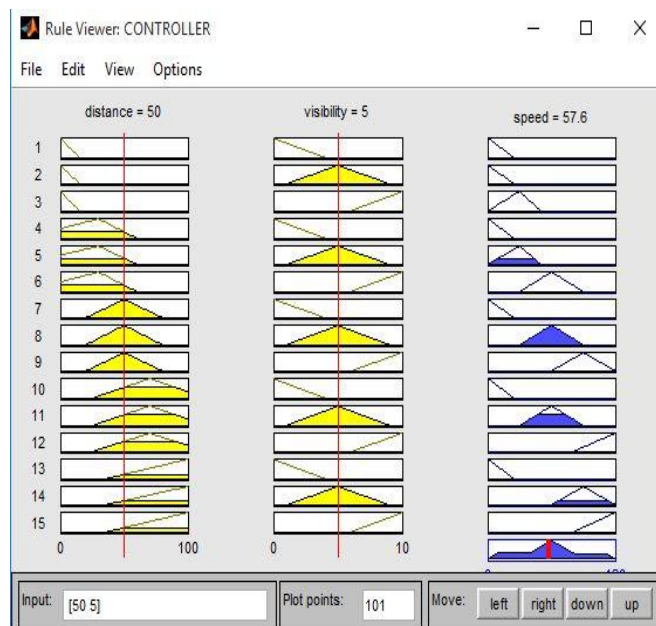


Figure 6: Rule Viewer

SURFACE VIEWER: It is a graphical interface through which we can examine the output surface of an FIS for the inputs given. The output (speed) and the inputs (distance and visibility) are marked along the axes. Distance is marked on the X-axis, Visibility is marked on Y-axis and the output (speed) is marked on the Z-axis.

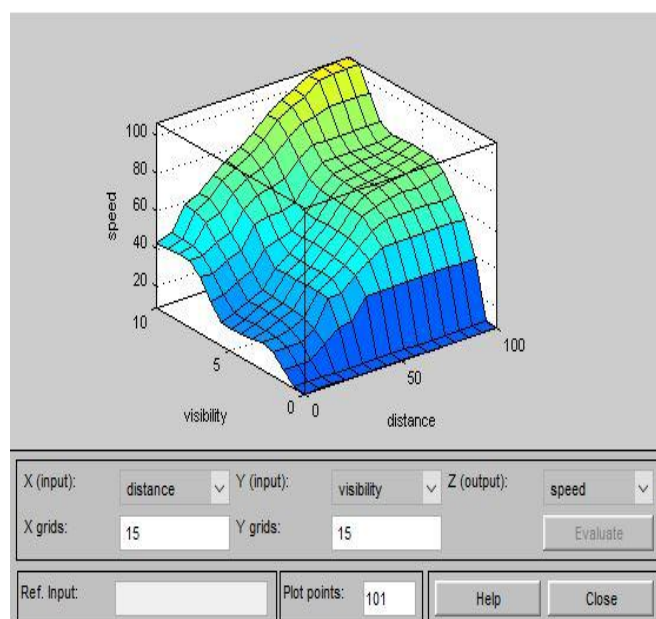


Figure 7: Surface Viewer

It is clear from the 3D figure that the output (speed) is varying as the input changes. The change in speed depends upon the inputs given and the rules laid down for the fuzzy logic controller to function.

6. Conclusion

The fuzzy logic speed controller was simulated in MATLAB and the results can be seen in figure 6 and figure 7. The simulated results have shown that speed of the train can be controlled using fuzzy logic and can be implemented with

few modifications for real-time application. From various simulation results, it can be seen that the speed thus obtained is approximately similar to the speed of the train on which the driving personnel would run the train by experience. The automation of train using fuzzy logic control can make the journey of the train safer.

References

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