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Automated Motor-Bike System using Fuzzy Logic

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Abstract - *In Boolean logic the truth-value can be 0 or 1. As against this in fuzzy logic, the truth-values of variables may be between 0 to 1 with 0 & 1 being extreme cases. Fuzzy logic finds its application in washing machine, image processing, decision-making, car control systems, Aerospace vehicle control system, etc. One such application, which we are taking under consideration in this paper, is Automated Motor-Bike control system. A fuzzy logic control method for controlling a motor bike, manually powered vehicle is disclosed which is used to assist a rider of the vehicle. The system manages the acceleration for riding a motor bike, a brake reducing the speed of a vehicle.*

1. INTRODUCTION

The actual trend of motor-bikes started within half of the 19th century. Over the years various innovations have enormously transformed the motorcycle form & features. Motor-bike design varies greatly to take a seat for a variety of various purposes.

After a certain period, the manufacturing industry was mainly dominated by Indian motorcycles. Due to increasing demand, many companies started launching various types of bikes like road racing bikes, street bikes & motocross. Now the generation of bikes growing tremendously, many companies as well as technological companies also decide to build automated bikes.

The fuzzy logic control has been an active research topic in nonlinear control theory since the work of Mamdani approach based on the fuzzy sets to deal with the control problems, which are hard to model. Due to their unstable nature, it is difficult to obtain a mathematical model of the motor-bike.

In this paper we are going to see, how the fuzzy logic helps to control motor-bike system. For that we used MATLAB application to find actual acceleration of motor-bike. Basically, fuzzy inference system provides output from inputs and these inputs will be captured by sensors or by automated parts.

2. FUZZY LOGIC

Fuzzy logic is a problem-solving control system that resembles human reasoning. This approach is how to human perform decision making.

The term **fuzzy** means the things which are not clear or are indistinct. Many times, in real-world we encounter n face many challenges or situations where we can't identify whether a situation is true or false. Fuzzy logic provides flexibility for reasoning. In this way, we can consider the unsureness of any situation and inaccuracies.

In Boolean, 0 represents the absolute false value and 1 represents absolute truth value. But in the fuzzy system, there is no logic for absolute false value and absolute truth. But in fuzzy logic, there is intermediate value too present which is partially false and true.

3. FUZZY LOGIC CONTROLLER

A fuzzy inference system is a system that uses fuzzy set theory to map inputs to outputs. Mamdani FIS and Sugeno FIS those are the two types of FIS. Mamdani FIS theory was presented in 1975 by Ebrahim Mamdani to control a steam engine and boiler combination by mixing a set of linguistic control rules in the form if then rule which are acquired from the experience of human operators [1].

Steps for computing the output in FIS:

1. Identify input & output variables and decide descriptor (Linguistic variables) for the input & output variables.
2. Define membership functions for each of input and output variables.
3. Form a rule base.
4. Rule Evaluation.
5. Defuzzification.

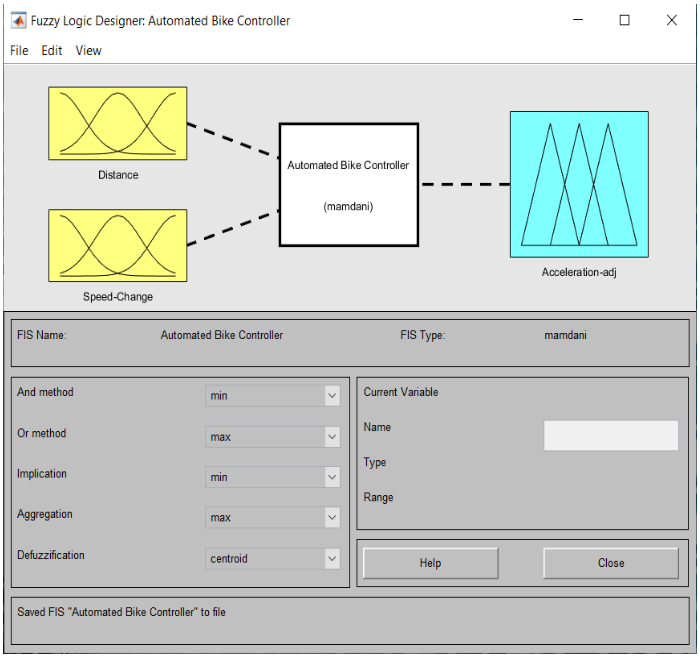

Fig -1: Fuzzy Model for Automated Bike Control System

As per the Mamdani FIS approach we are going to consider two input variables – Distance (distance between current Motor-bike and the any obstacle) and Speed change. The fuzzy controller adjusts one output i.e. Acceleration.

The output comes from the fuzzy controller system will decides how much acceleration is required for Motor-Bike. For E.g. - By considering situation, if any obstacle comes in front of your Motor-Bike (any obstacle it can be any vehicle or any person, etc.). Then by keeping records of Motor-Bike, it will generate an appropriate output.

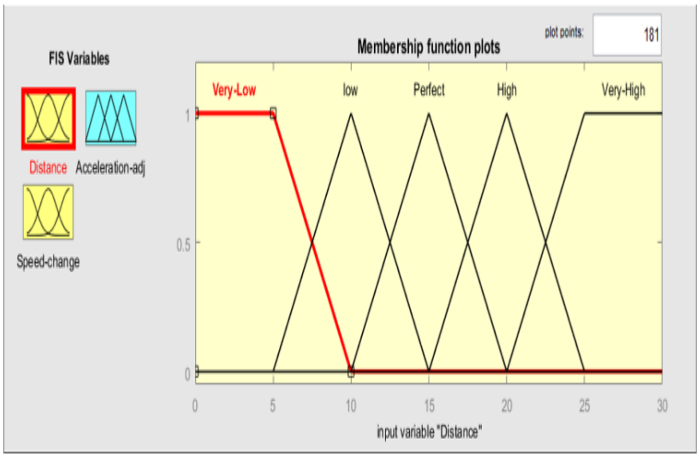

Fig -2.1: Linguistic variables & Membership function of Distance

Table -1: Linguistic representation of fuzzy input variable Distance

Membership Function	Range (0,30)	Type
Very low	[0,0,5,10]	Trapmf
low	[5,10,15]	Trimf
Perfect	[10,15,20]	Trimf
High	[15,20,25]	Trimf
Very high	[20,25,30,30]	Trapmf

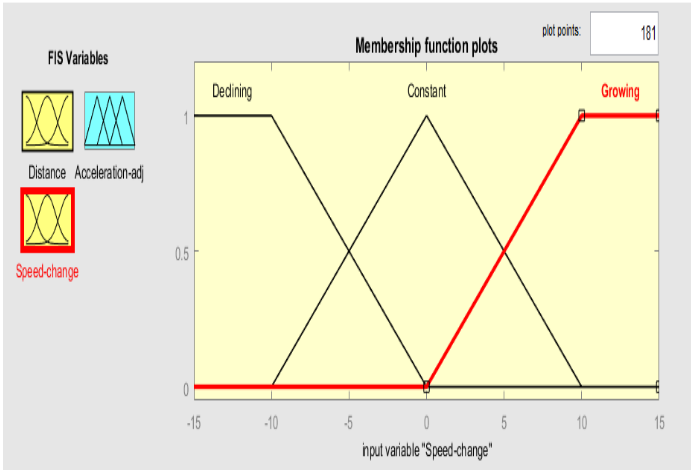

Fig -2.2: Linguistic variables & Membership function of Speed change

Table -2: Linguistic representation of fuzzy input variable Speed change

Membership Function	Range (-15,15)	Type
Declining	[-15, -15, -10, 0]	Trapmf
Constant	[-10, 0, -10]	Trimf
Growing	[0,10,15,15]	Trapmf

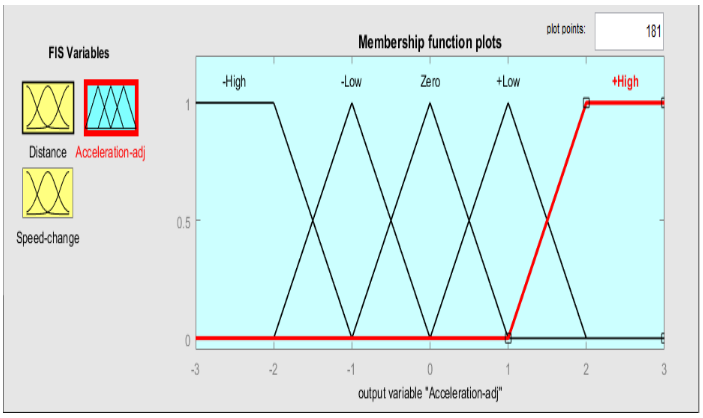

Fig -2.3: Linguistic variables & Membership function of Speed change

Table -3: Linguistic representation of fuzzy input variable Acceleration

Membership Function	Range(-3,3)	Type
-High	[-3,-3,-2,-1]	Trapmf
-Low	[-2,-1,0]	Trimf
Zero	[-1,0,1]	Trimf
+Low	[0,1,2]	Trimf
+High	[1,2,3,3]	Trapmf

Fig. 2.1, 2.2, 2.3 represents input and output membership function with the linguistic variables. Table I, II, III represents fuzzy range of input and output variable respectively.

The fuzzy rule base given below:

Table -4: Fuzzy Rule Set of Mamdani FIS

		Distance				
Speed Change		v. low	Low	Perfect	High	V. high
	Declining	-low	zero	+low	+high	+high
	Constant	- high	-low	Zero	+low	+high
	Growing	- high	- high	-low	zero	+low

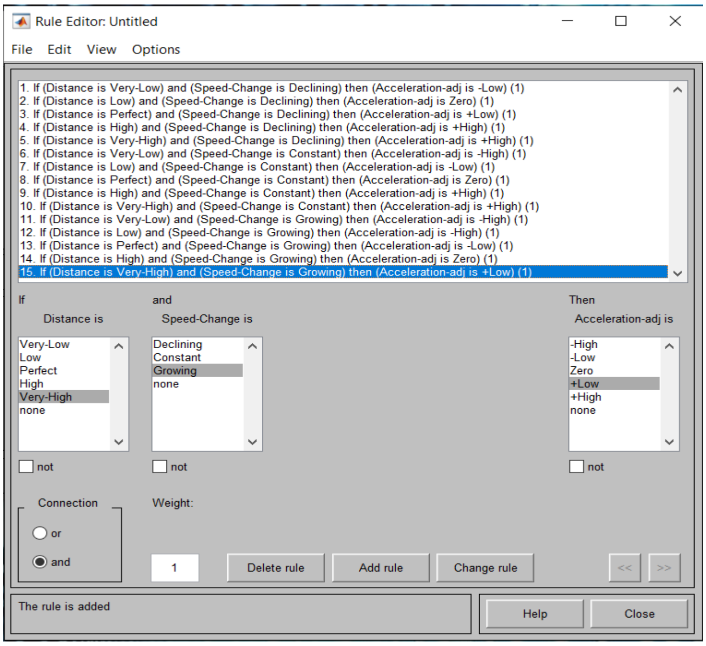

Fig -3: MATLAB – Fuzzy Rule Set

By considering example, Suppose the input variables – a) Distance between the bike and obstacle is 13m & speed is changed by -2.5 m/s^2.

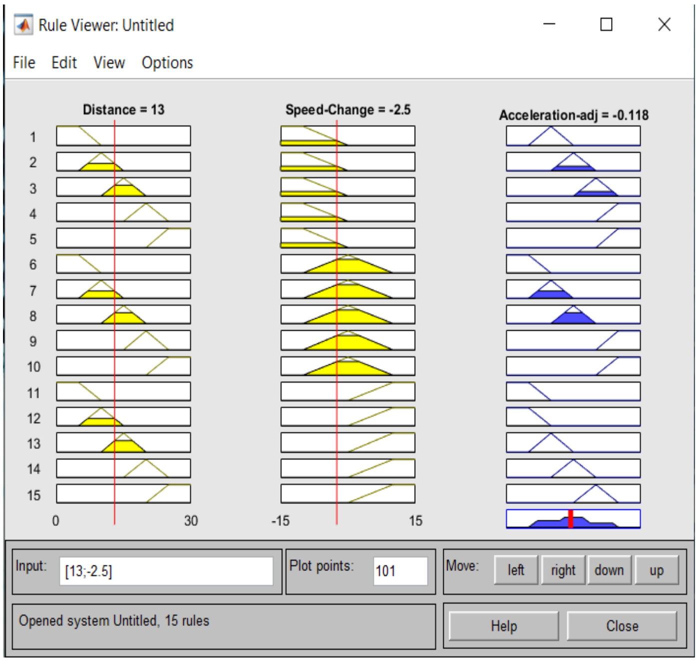

Fig -4: Rule viewer of motor-bike FIS

Fig.4 shows the fuzzy inference rules of model as shown in MATLAB. This combines the Distance & Speed of motor-bike to calculate the Acceleration. For the input values Distance is Perfect(medium) & Speed is changing by -2.5m/s^2 which is constant then acceleration adj.= Zero (maintaining the acceleration). Now in this we can calculate the crisp value by applying defuzzification method.

There are commonly two method are used for defuzzification, center of area (COA) and mean of maximum (MOM). Here, the COA method is selected as the defuzzification strategy. Because the universe of discourse of the output value, the acceleration, is continuous, then, the COA strategy generates an output control action of,

$$a^*_{COA} = \frac{\int \mu A(a).a\ da}{\int \mu A(a).da}$$

After defuzzification Acceleration adj. = -0.118 which is medium means bike needs no acceleration.

The following table indicates few results of Bike Control System.

Case	Distance(meters)	Speed change(m/s^2)	Acceleration adj. (m/s^2)
1	22	10	0.419
2	25	-8	2.2
3	18	2	1.04

From the above fuzzy controller system, we got to know how the acceleration change is required for controlling bike. Also, there are some situation where speed control system is useful for controlling bike & the situations are like traffic situation, overtaking, etc. This can be achieved with the combination of hardware & software (hardware is like sensors & software are like fuzzy control system).

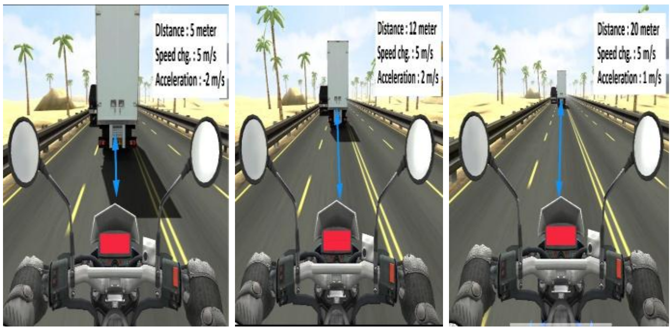

Fig -5: The ACC+Stop&Go controller's performance in an automated motor-bike.

ACC +Stop & Go (Traffic Situation):
With ACC, the automated controller system can change the bike speed to keep a distance from the lead vehicle. As an example, the lead vehicle might come to a complete stop (rest position) owing to a traffic jam. In this case, the ACC must stop the bike or should decrease the acceleration of bike; when the road is clear, the ACC re accelerates the bike until it reaches the target speed. Combining ACC with stop & go maneuvers increases driving comfort, regulates traffic speed, and breaks up bottlenecks more quickly. Many rear-end collisions happen in stop-and-go situations because of rider distractions. But there is one drawback in the ACC+Stop & go situation is that, if rider is in traffic mode and the bike is in automated mode in that case the rider needs to balance the bike when the bike is about to stop. To overcome this, there is an alternate solution — automatic bike stand or the self-balancing bikes.

Figure 5 shows our ACC+Stop & Go controller's performance in our automated smart-bike. At the experiment's beginning, the bike starts moving, speeds up and eventually stops because the lead vehicle is blocking the way. The lead vehicle then starts moving, increases its speed, and brakes again just because of congested traffic situation. After some seconds later, the motor-bike starts again, eventually stopping behind the lead vehicle [2].

Overtaking
The system can also manage obstacles or other vehicles in the vehicle's path by calculating when the bike should change lanes to overtake the obstacle. First,
• the bike must be in the straight-lane driving mode,
• check the left or right lane must be free, and
• there must be enough space for the overtaking.

Given this, overtaking occurrences as follows:
1. Initially, the bike is in straight-lane mode.
2 The riding mode changes to lane change mode, and the bike moves into the left side of lane or right side of lane.
3. The riding mode changes to straight lane mode until the bike has crossed the vehicle or obstacle.
4.The riding mode again changes to lane-change mode, and the bike returns to its original position & riding continuous as usual.

4. CONCLUSIONS & FUTURE SCOPE

In this current generation, we mostly preferring normal gear motor-bike or non-gear bikes but in the future, we definitely get hands-on automated motor-bike. Automated motor-bike are future of our world with some advanced versions like the bike will be self-balancing motor-bike with the automated system.

Basically, to ride motor-bike we have to give acceleration as per our judgment but in terms of automated bike, the system or machine needs to control bike & this controlling system we discussed in this paper. For that, we used a Mamdani fuzzy algorithm to calculate acceleration in the mathematical format. MATLAB software is used to simulate the model with some inputs & rules.

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