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Fuzzy Logic Based Automatic Vehicle Collision Prevention System

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***Abstract*—More than 90 percent of all traffic accidents are caused by human error and their involvement in different activities while driving. Therefore we have proposed an Autonomous Vehicle Collision Prevention System. The system is capable to apply Brakes (B) of Vehicle autonomously on time to minimize the risk of destruction. It involves Fuzzy logic based software simulation results comparing with mathematical Mamdani model. This system consists of three inputs and one output. These inputs are DBV (Distance between Vehicles), VS (Vehicle Speed) and SFC (Static Friction Coefficient), one output is B (Brakes). MATLAB based software simulation results of the system and mathematically modeled results are comparing to generate the difference error. Such systems allow Vehicle to apply Brakes (B) according to the situation needed in case of driver negligence.**

Key Words: Distance between Vehicles, Vehicle Speed, Static Friction Coefficient

I. Introduction

In this global era of world everything is becoming fast day by day. Fast Aeroplanes, fast vehicles, trains are used to save the precious time of people. Although these fast moving vehicles save time but a little negligence of drivers and operators risks a lot of precious lives. Every year more than 1.3 million people are died in road accidents. Now a days modern inventions, Autonomous systems making the lives of people secure. Such systems automatically take control of the vehicle in case of any human error. We also introduce such system to avoid from collisions and fatal accidents due to driver negligence.A path-tracking controller of a bi-steerable cybernetic car with an anti-collision behavior is important. His proposed method based on Laser Range Data consists of estimating the trajectories and behavior of surrounding objects. The velocity planner and the anti-collision system are fundamental modules in the architecture. The PTC showed good performance and smooth path tracking in simulation using fuzzy technique[1].

II. Previous Work

The author outlined a design for collision avoidance. An impressive management approach has been made to computationally apply the approximate reasoning necessary for managing the debts built in the collision avoidance problem. He developed a reaction control system using fuzzy logic. His system performs an effective reactive control technique as it detects the immediate environment and reacts (with the aid of approximate reasoning) to current sensory data[2]. This paper based on the autonomous land vehicle (ALV) navigation. In this paper, a hierarchical navigating system that constructs an image to avoid hindrance similar to the capability of human vision is introduced. ALV acquire the information (such as imprecise view angle and rough depth etc.) to assess the best feasible steering direction with the stereo vision camera during navigating. He puts in Sugeno type model to obstacle avoidance of the autonomous land vehicle (ALV) navigating[3]. System for collisions between road vehicles moving with high speed or for preventing rear end collisions when there is not enough separation between the vehicles. In his paper he presented the development of a controller to perform emergency lateral collision avoidance. This paper indicates noticeable enhancement in collision avoidance at vehicle speeds up to 100 [km/hr] using the integrated automatic steering and braking. The feedback steering control loop technique minimizes the effort necessary for the brake controller, while its simple gain matrix supplies quick, sharp way for the overall controller performance to be fine-tuned in response to experimental test data[4]. Brand new idea presenting an exact measurement between automobile distance by the use of monocle camera and line laser. Using inter vehicle distance measuring technique which is in wide spread use in driving assistance system such as adaptive cruise control. He represents the fault in distance measuring that is low in day and night time as well[5].

Control system designed that might be embedded in an automobile in order to get rid of the driver's reaction time from the situation. Author connected two fuzzy controllers in cascade to evaluate most likely accident situations based on the separation distance between vehicles, their relative speed and a static friction coefficient that represents the road conditions. The designed provide the suitable brake pressure needed to prevent collisions while giving a smooth ride for the vehicle's passengers. The two-controller system trained with a genetic algorithm worked very well for the stated problem[6]. Modern car-following and lane-changing collision prevention system based on cascaded fuzzy inference system (CFIS). Author combined the lane-changing & car-following to save the processing time. Monte Carlo simulations were used to demonstrate that the CFIS collision prevention system could provide a safe, reasonable, and comfortable drive for vehicle following and lane changing[7]. Comparison is made between the responses of two different controllers using in the automated car braking system. The fuzzy logic controller is the first order method second order method is PID controller. Based on simulation result, a fuzzy controller is an automatic controller, a self-acting or self-regulating mechanism that controls an object in accordance with a desired behavior[8]. Novel approach is made to make the highway system more effective, the automated lane changing model without collision. Through this model, studied that vehicles on the highway can coordinately drive to let the faster vehicles pass the highway more quickly and the slower vehicles maintain desired speeds. To make his model more realistic he used traffic density as the most important parameter of the controller. The paper describes control methods based on the knowledge Slower traffic yield to the right and simulation results show the controller perform better to improve the highway throughput[9]. An Obstacle is avoidance for mobile robots in a narrow area with static and dynamic obstacles. His research work based on selection of the sub-target points of robot's movement called "soft target" which is a target set defined as all possible and reachable via-points in a navigation space, the membership value of each element between 0 to 1. Simulation results show the validity and effectiveness of the proposed method[10]. In Path-tracking controller of a bi-steerable cybernetic car with an anti-collision behavior, the proposed method based on Laser Range Data consists of estimating the trajectories and behavior of surrounding objects. The velocity planners and the anti-collision system are fundamental modules in the architecture. The PTC showed good performance and smooth path tracking in simulation using fuzzy technique[11]. The Author presents a controller based on an adaptive network fuzzy inference system (ANFIS) for the car-following collision prevention system to non linearly control the speed of the vehicle. 25 rules defines to construct interface system. On the basis of simulation result, he present that his proposed controller can solve the problems of the oscillations for the final distance between the leading vehicles (LV) and the following vehicle (FV) and relative speed. The required processing time to achieve safe distance between the LV and the FV is about 78 s, which is faster than the other models with assistance of providing comfortable drive[12].

III. Aim of the Research

The aim of this research is to provide the better, reasonable and secure facilities to assist driver on the road. Such type of systems not only plays an essential role in the safety of the driver, but for pedestrians also. The simulation has been performed by using Mamdani method in fuzzy logic to design a fuzzy logic controller (FLC) to control the parameters to make available the most suitable conditions for safe and secure journey.

IV. MATLAB Simulation

The simulation has been done using fuzzy logic controller (FLC) as shown in Fig. 1. Three inputs and one output have been defined. Firstly, we consider the distance between vehicles with its membership functions with defined specific ranges and regions. The input distance between vehicles having membership functions with their defined ranges is shown in Fig. 2.

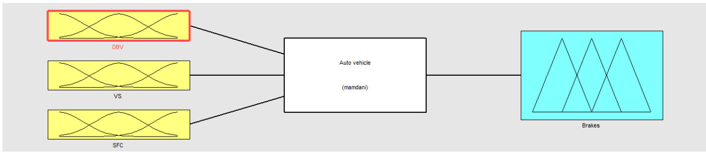

Fig. 1. FIS Editor for FLC

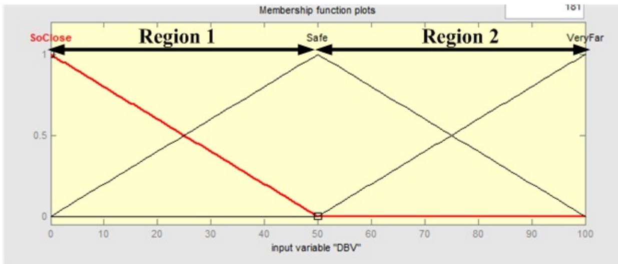

Fig. 2. Input Distance Between Vehicles Ranges

Now we consider second input vehicle Speed with its membership functions ranges and regions. We have three membership functions: Slow, medium and Fast. Slowzone is from 0 to 50%, Medium zone from 0 to 100% and Fast from 50 to 100%. The two regions present the whole Vehicle Speed range as shown in Fig. 3.

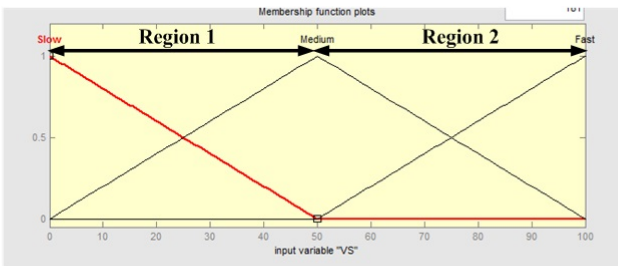

Fig. 3. Input Vehicle Speed Ranges and Region

The third input variable is Static Friction Coefficient. The Static Friction Coefficient ranges and region is shown in figure 4.

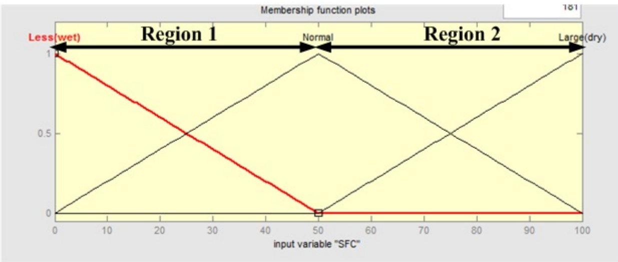

Fig. 4. Input SFC Ranges and Region

Now we have considered the output Brakes as: controlling the speed of the vehicle. The output brakes with membership function performing particular operation for specific ranges are shown in Fig. 5 The membership functions and ranges for output are shown in Table 1.

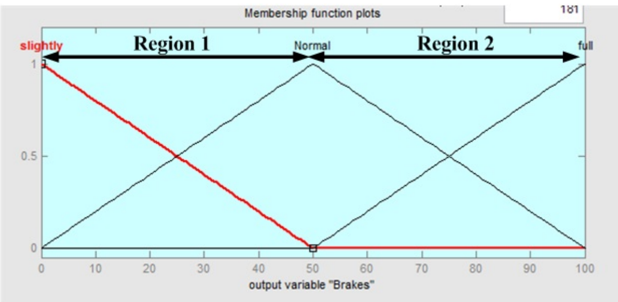

Fig. 5. Output Brakes Ranges

Membership Function	*Ranges in %*	*Brakes*
MF1	0-50	Slightly
MF2	0-100	Normal
MF3	50-100	Full

TABLE I
MEMBERSHIP FUNCTIONS AND RANGES FOR OUTPUT BRAKES

There are three input variables and six linguistic variables. Each input variable has its own effect on output. The formula for linguistic fuzzifier output is fn[m] as shown in Table II. Here n= number of input, m= number of member ship function.

Input Variables	*Linguistic Fuzzifier Output*	*Region 1*	*Region 2*
Distance between Vehicle	f1	f1[1]	f1[2]
	f2	f1[2]	f1[3]
Vehicle Speed	f3	f2[1]	f2[2]
	f4	f2[2]	f2[3]
Static Friction Coefficient	f5	f3[1]	f3[2]
	f6	f3[2]	f3[3]

TABLE II
LINGUISTIC VALUES OF FUZZIFIER OUTPUT

The Fuzzy Logic Rules used in the FLC are developed by the formula = m^n. Here is n=number of inputs and m=number of membership functions each input contain. So the fuzzy rules are $3^3 = 27$ rules. The fuzzy rules editors in which all the rules are defined and these rules are same like if and then condition. These fuzzy rules go for rule evaluation in the inference system. The Fuzzy Logic Controller rule viewer is shown in Fig. 6.

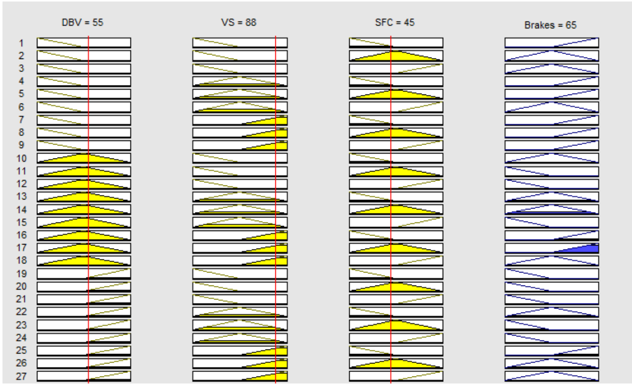

Fig. 6. FLC Rule Viewer

Here are few surface viewer three dimensional graphs between inputs and the output separately. These graphs show the response of the controller to maintain proper brakes in case of any unpredictable situation.

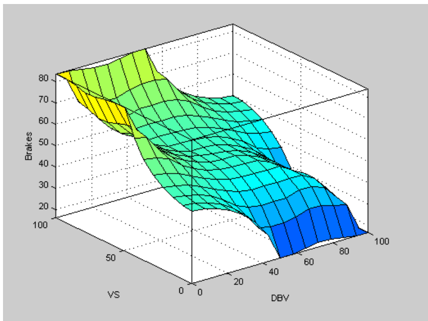

Fig. 7. Surface Viewer Graph between Distance between vehicles and Vehicle Speed

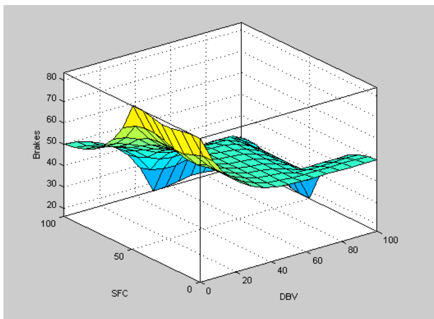

Fig. 8. Surface Viewer Graph between Distance between vehicles and Static friction coefficient

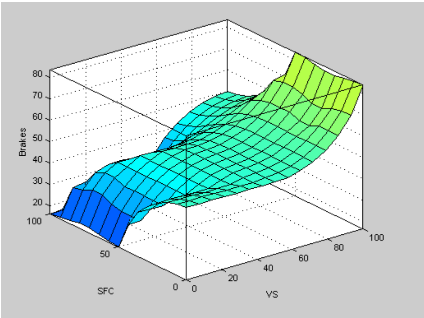

Fig. 9. Surface Viewer Graph Static friction coefficient and Vehicle Speed

V. Design Algorithm

The fuzzy logic based control system for the automatic vehicle collision prevention system has been presented. The three important inputs are distance between vehicles, vehicle speed, and static friction coefficient. The output can be controlled by different combinations of input parameters. Taking inputs and outputs values in % and using Mamdani model, the mathematical results are as follows.

Inputs: Distance between vehicle: 55, Vehicle Speed: 88, Static friction coefficient: 45

Outputs: Brakes: 65

A. Finding of Linguistic variables for Distance between Vehicle

Distance between vehicles is an input parameter for a fuzzy logic controller, its value lies in region 2. If we consider the membership functions graphs for its values (MFs) are: Safe (S), Very Far (VF). The membership functions f1 and f2.

$$f_1 = \frac{100-55}{100} = \frac{45}{100} = 0.45 .... (1)$$

$$f_2 = 1 - f_1 = 1 - 0.45 = 0.55 .... (2)$$

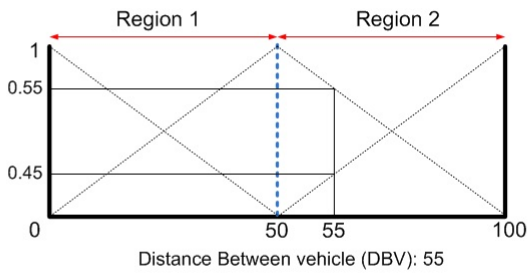

Fig. 10. Finding Linguistic Variables for Distance between Vehicle

B. Finding of Linguistic variables for Vehicle Speed

Vehicle Speed is the second input parameter for FLC having its value is also present in Region 2. The membership functions for this particular value of vehicle speed are (MFs): Medium (M), Fast (F). The membership functions values are f3 and f4 find as follows.

$$f_3 = \frac{100-88}{100} = \frac{12}{100} = 0.12 .... (3)$$

$$f_4 = 1 - f_3 = 1 - 0.12 = 0.88 .... (4)$$

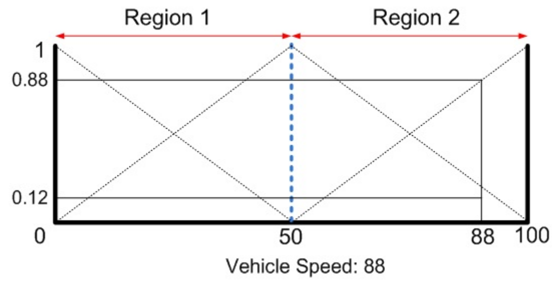

Fig. 11. Finding Linguistic Variables for Vehicle Speed

C. Finding of Linguistic variables for Static Friction Coefficient

The third input parameter for the fuzzy logic controller we are designing is Static friction coefficient. Its specific value is in % which lies in region 1. If we consider the membership functions graphs for its values (MFs) are: Less (Lw), Normal (N).The membership functions f5 and f6 are as follows.

$$f_5 = \frac{50-45}{50} = \frac{5}{50} = 0.10 .... (5)$$

$$f_6 = 1 - f_5 = 1 - 0.10 = 0.90 .... (6)$$

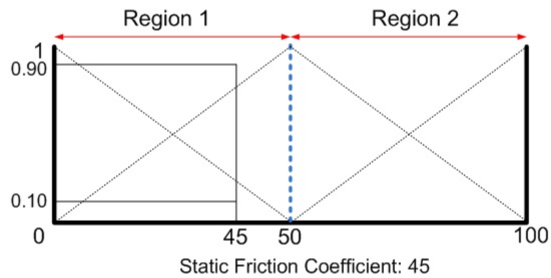

Fig. 12. Finding Linguistic Variables for Static Friction Coefficient

D. Single ton Values finding for Input Parameters

After finding the linguistic variables values for input parameters, the single ton values of inputs also find out. Single ton values are actually the output parameters peak values for composite rules.

There are three membership functions used for each rule of inference engine. The specified rules having their membership functions are shown in Table IV, but we will consider only the least one as we are using AND logic.

Rule No	DBV	VS	SFC	Brakes	Si Values
R0	Safe	Slow	Normal	Normal	0.5
R1	Safe	Slow	Large	Normal	0.5
R2	Safe	Medium	Normal	Full	1
R3	Safe	Medium	Large	Full	1
R4	Very Fast	Slow	Normal	Normal	0.5
R5	Very Fast	Slow	Large	Slightly	0
R6	Very Fast	Medium	Normal	Full	1
R7	Very Fast	Medium	Large	Normal	0.5

TABLE III
SINGLE TON VALUES OF COMPOSITE RULE FOR BRAKES

Rule No	Membership Functions
R0	f1 ∧ f3 ∧ f5 = 0.45 ∧ 0.12 ∧ 0.10 = 0.10
R1	f1 ∧ f3 ∧ f6 = 0.45 ∧ 0.12 ∧ 0.90 = 0.12
R2	f1 ∧ f4 ∧ f5 = 0.45 ∧ 0.88 ∧ 0.10 = 0.10
R3	f1 ∧ f4 ∧ f6 = 0.45 ∧ 0.88 ∧ 0.90 = 0.45
R4	f2 ∧ f3 ∧ f5 = 0.55 ∧ 0.12 ∧ 0.10 = 0.10
R5	f2 ∧ f3 ∧ f6 = 0.55 ∧ 0.12 ∧ 0.90 = 0.12
R6	f2 ∧ f4 ∧ f5 = 0.55 ∧ 0.88 ∧ 0.10 = 0.10
R7	f2 ∧ f4 ∧ f6 = 0.55 ∧ 0.88 ∧ 0.90 = 0.55

TABLE IV
MEMBERSHIP FUNCTIONS FOR COMPOSITE RULES

The mathematical formula for Mamdani Model is as follows:

$$MamdaniModel = \left[\frac{\sum R_i \times S_i}{\sum R_i}\right] \times 100$$

Where Ri are the values which are used in the table IV same as Si are the singleton values are for output. We conclude the design values for Brakes.

E. Calculation and Observation for Brakes

The calculations for output Brakes involve three values as OFF = 0.16, LITTLE = 0.46, LARGE = 0.75

$$[\sum S_i \times R_i] = S_0 \times R_0 + S_1 \times R_1 + S_2 \times R_2 + S_3 \times R_3 + S_4 \times R_4 + S_5 \times R_5 + S_6 \times R_6 + S_7 \times R_7$$

$$\sum S_i \times R_i] = 1.08$$

$$[\sum R_i] = R_0 + R_1 + R_2 + R_3 + R_4 + R_5 + R_6 + R_7$$

$$[\sum R_i] = 1.64$$

$$Brakes = \left[\frac{\sum R_i \times S_i}{\sum R_i}\right] \times 100$$

$$Brakes = \left[\frac{1.08}{1.64}\right] \times 100$$

Brakes = 65.85

Simulated Value = 65

Mathematically designed value = 65.85

Difference = Design Value - Simulated Value

Difference = 65.85 - 65

Difference = 0.85

$$Error = \left[\frac{Difference}{ActualValue}\right] \times 100$$

Error = 1.30%

F. Comparison between Simulated and Calculated Results.

The comparison between Matlab simulated values and calculated values with % errors are as follows in Table V.

Result	Brakes
Designed Value	65.85
Simulated Value	65
% Error	1.30%

TABLE V
COMPARISON BETWEEN SIMULATED AND DESIGNED VALUE

VI. CONCLUSION

Designing a controller for Vehicle collision prevention system is an essential and a beneficiary step towards automatic control systems. In order to design such system three important inputs for the vehicles are considered. Vehicle speed, distance from leading vehicle and Static friction coefficient between the tires of vehicle and road. The SFC values are different for wet, normal and dry surfaces. We have used fuzzy logic to implement the Mamdani model. Different other techniques like Simulink and neural networks are being used to design a controller for inputs and outputs. In this system, FLC is used to obtain controlled outputs depending upon the conditions on the road. The results are displayed in surface viewer graphs with respect to the defined rules belonging to their specific assigned membership functions. Our designed system has also been verified in Mamdani formula by putting specific values in outputs and inputs. There is a minor difference between Matlab simulated values and formula oriented mathematical calculations. The generated error is about 1.30%.

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