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RESEARCH ARTICLE

Design of ANFIS System for Efficient Throttle and Brake Control of Vehicles

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Abstract—* *The ANFIS is an Adaptive Neuro-Fuzzy Inference System that has a major role in control of nonlinear systems has been gaining special attention in the use of Artificial Intelligent techniques. The ANFIS system is one of the best alternatives to exploit the human knowledge. Indeed, in commercial vehicles, its aim is to progressively implement safer and more comfortable control for drivers, acting on throttle and brake. In this work, we utilize a Adaptive Neuro-Fuzzy Inference Systems to use human driving knowledge to tune and adjust the input-output parameters of a fuzzy if then system. The detail survey based on designing to control the system for controlling throttle and brake of vehicles application ,shows that the ANFIS is the best suitable alternative for methods which were used earlier.

Index Terms*— *Introduction, Throttle and Brake Control using Fuzzy, Throttle and Brake Control using ANFIS, Results, Conclusions, References

1. INTRODUCTION

In general, the road accidents mainly occur by not maintaining a safe distance between two vehicles, and ignoring traffic signals by a vehicle, all of which can be associated with excess or inappropriate speed. Crush Control (CC), emergency stop and velocity tracking control are the more common throttle and brake control applications, which have been extensively, studied in the fields of mobile robots and Intelligent Transportation Systems (ITS) [3]. Indeed, in commercial vehicles, it is progressively implementing safer and more comfortable control for drivers, acting on throttle and brake. The maximum speed that vehicles must not exceed on urban traffic ways and on highways through urban areas is established with general character at 50 kilometers per hour[4].

H. Nguyen, N.Rasad, C.Alker and E. Walker (2003) Fuzzy mainly deals with the If-Then rule [1]. The mathematical modeling of fuzzy concepts was first presented by Professor Lotfi Zadeh in 1965.A membership function for a fuzzy set A on the universe of discourse X is define as $\mu A : X \rightarrow [0, 1]$where each element of x is mapped to a value between 0 and 1[3]. This value is called membership value or degree of membership. There is different type of membership function triangular, trapezoidal, Gaussian, and sigmoidal Z- and S-functions.

$$A(x) = \begin{cases} \alpha\left(\dfrac{x-a}{c-a}\right) & \text{if } a \le x \le c \\ \alpha\left(\dfrac{x-b}{c-b}\right) & \text{if } c \le x \le b \\ 0 & \text{otherwise} \end{cases}$$

The triangular function A with end points (a, 0) and (b, 0) ,and highpoint(c, α) is defined by

$$A(x) = \begin{cases} \alpha\left(\dfrac{x-a}{c-a}\right) & \text{if } a \le x \le c \\ \alpha & \text{if } c \le x \le d \\ \alpha\left(\dfrac{x-b}{d-b}\right) & \text{if } d \le x \le b \\ 0 & \text{otherwise} \end{cases}$$

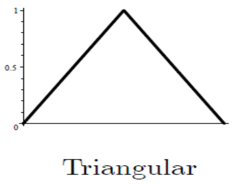

Fig a Triangular membership function

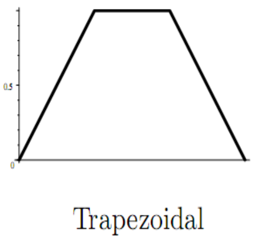

Fig b. Trapezoidal membership function

The trapezoidal function B with end p oint s (a, 0) and (b, 0) , and high points (c, α) and (d, α) is denoted by Gaussian functions:- The Gaussian functions, the familiar bell-shaped curve. A generalized bell curve, is given by functions of the form

$$A(x)=1/(1+ |(x-c)/a|^{2b})$$

The parameter **c** determines the center of the curve, and **a** and **b** determine its shape[8].

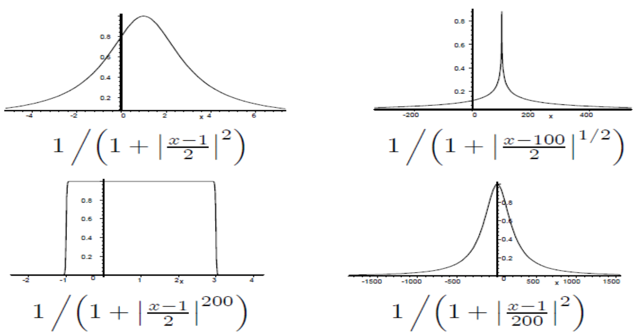

Fig c [3]. Gaussian membership function

The S- and Z-functions are sigmoidal functions of the form[10]

$$A(x)=1/(1+e^{-(x-m)\sigma})$$

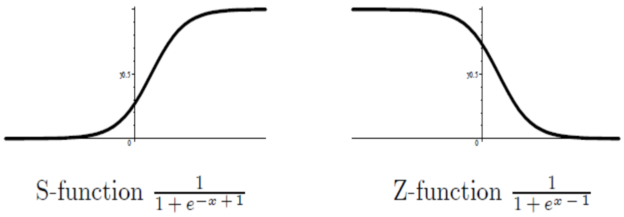

Fig d sigmoidal Z- and S-functions.membership function

Why neural and fuzzy combine together?

If the data are pairs of numbers, we may turn to a neural method, and if the data are rules, fuzzy methods may be appropriate[4]. Neural methods provide learning capability, whereas fuzzy methods provide flexible knowledge-representational capability[7]. Integrating these two methodologies, in control and in intelligent technologies in general, can lead to better technologies that take advantage of the strengths of each methodology and at the same time overcome some of the limitations of the individual techniques[8].

Jyh-Shing Roger Jang (1993) The ANFIS is Adaptive-Network-Based Fuzzy Inference System.The ANFIS has mainly consist of five layers, each layer has a specific task[2] .There is mainly two types of node square node and circular node. The square node having adaptive parameter, that will be adjustable during training phase. The circular node is fixed parameter.

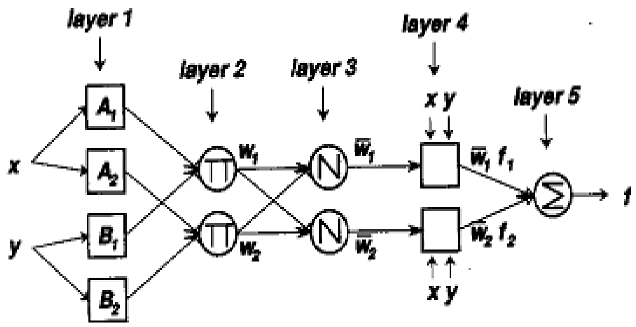

Fig e [2] ANFIS system genral architecture

Layer 1: It is called as fuzzification layer. Every node i in this layer is a square node with a node function

$$O_i^1=\mu_{Ai(x)}$$

where x is the input to node i, and Ai is the linguistic label (small , large, etc.) associated with this node function is commonly known as the membership function of A, and it evaluate the degree to which the given x satisfies the quantifier Ai[6]. Usually we choose to be bell-shaped with minimum equal to 0 and maximum equal to 1, such as

$$\mu_{Ai}(x)=1/(1+|(x-c_i)/a_i|^{2b_i})$$

where {**ai, bi, ci**} is the parameter set. As the value of these parameters varies, the bell-shaped functions vary respectively, thus showing different forms of membership functions on linguistic label Ai. Any piecewise and continuous differentiable functions, such as commonly used trapezoidal shaped membership functions, are also good candidates for node functions in this layer. Parameters consisting in this layer are referred to as premise parameters [7].

Layer 2: It is called as rule antecedent layer. Every node in this layer is a circle node labeled Π.
This multiplies the incoming signal and sends the product out. For instance,

$$w_i = \mu_{A_i}(x) \times \mu_{B_i}(y),\ i = 1, 2.$$

Each node output represents the firing power of a rule. (In fact, other T-norm operators that perform generalized AND can be used as the node function in this layer.)

Layer 3: It is called as normalization layer. Every node in this layer is a circle node labeled N. The ith node evaluate the ratio of the ith rule's firing strength to the sum of all rules firing strengths:

$$\overline{\omega}_i = \frac{\omega_i}{\omega 1 + \omega 2} \quad , i = 1, 2$$

For convenience, outputs of this layer will be called normalized firing strengths.

Layer 4: It is also called as rule consequent layer. Every node i in this layer is a square node with a node function.

$$O_i^4 = \overline{w}_i f_i = \overline{w}_i (p_i x + q_i y + r_i)$$

where $\overline{w}_i$ is the output of layer 3, and {pi, qi, ri} is the parameter set. Parameters on this layer will be considered to as consequent parameters.

Layer 5:

It is also called as output layer. The single node in this layer is a circle node labeled summation that computes the overall output as the summation of all incoming signals, i.e

$$O_1^5 = overall\ output = \sum_i \overline{w}_i f_i = \frac{\sum_i w_i f_i}{\sum_i w_i}$$

J.E. Naranjo (2006)The main purpose of this work is to improve previous fuzzy controllers developed in the group , taking the experience of different expert drivers and considering the comfort and efficient use of actuators. For this purpose, a Adaptive Network Based Fuzzy Inference System (ANFIS) is used, where the previous rule base and the experience of the expert drivers have been used as start point[6],[11]. These experts are drivers that know the feature of the vehicle and the tested tracks, which has some slopes and curves that have an effect on vehicle dynamic. To keep the reference speed in these conditions is difficult for human drivers.

2. Throttle and Brake Control using Fuzzy

José E. Naranjo, Carlos González, Member, Ricardo García, and Teresa de Pedro (2006). The gasoline vehicle used here was implemented with capable results. Detail on the membership function, rule base explanation, singleton outputs can be originated in. This controller defines two fuzzy outputs for every one actuator, the throttle and brake. Also, a change in the output of the control make that both actuators cannot work at the same time[12].

The input variables of the controller are:

Speed error (fig f) and acceleration (fig g). The first is the changed between the reference speed and the actual speed of the vehicle (km/h)[14]. The second is the acceleration or the variant of the vehicle speed at each time instant. The same membership functions are used to describe both input variables.

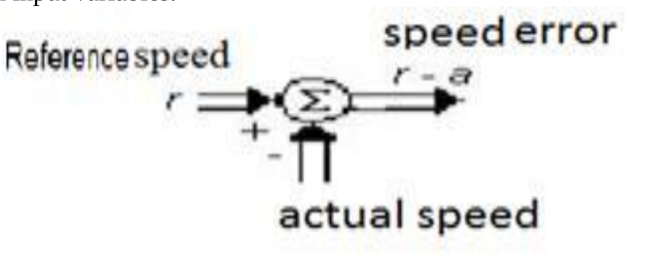

Fig f. Speed Error

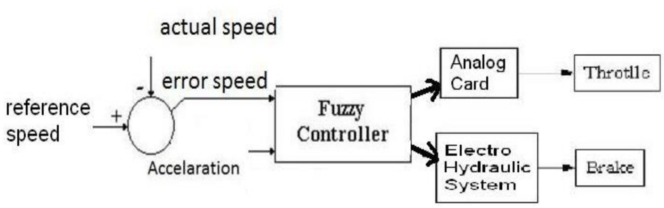

Fig g. Fuzzy control

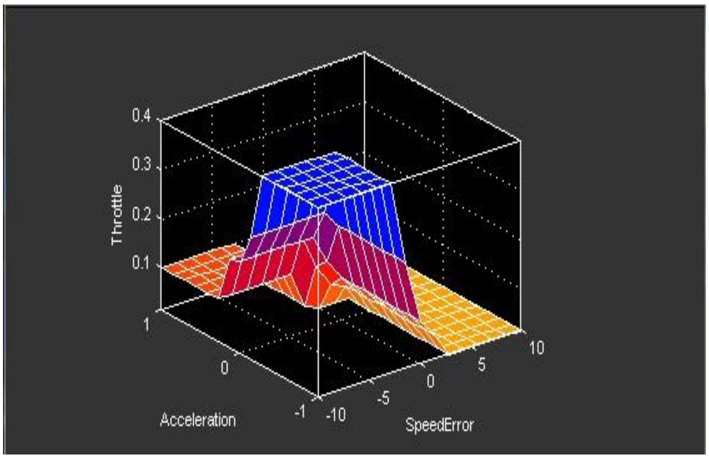

Fig h. .Fuzzy controller Throttle output

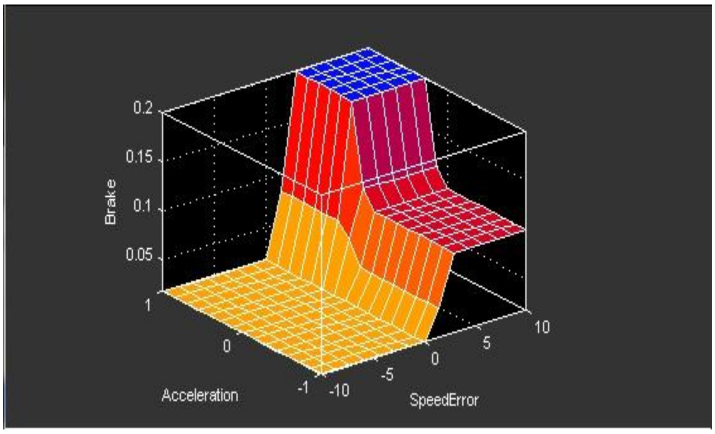

Fig i . Fuzzy controller Brake output

Throttle rule base:-

The fuzzy control system consists of its fuzzy rules.
In our case, they are[13]:

- R1: **if** *acceleration* **is** positive and *speed error* **is** null **then** *throttle* t00
- R2: **if** *acceleration* **is** null and *speed error* **is** negative **then** *throttle* t02
- R3: **if** *acceleration* **is** negative and *speed error* **is** null **then** *throttle* t01.
- R4: **if** *acceleration* **is** null and *speed error* **is** null **then** *throttle* t01
- R5: **if** *speed error* **is** positive **then** *throttle* t00
- R6: **if** *acceleration* **is** positive *and speed error* **is** negative **then** *throttle* t01
- R7: **if** *acceleration* **is** negative *and speed error* **is** negative **then** *throttle* t04

Brake rule base:-

The rule base used to control the brake is as following:

- R8: **if** *acceleration* **is** null and *speed error* **is** positive **then** *brake* b01
- R9: **if** *speed error* **is** null **then** *brake* b00
- R10: **if** *acceleration* **is** negative *and speed error* **is** positive **then** *brake* b01
- R11: **if** *speed error* **is** negative **then** *brake* b00
- R12: **if** *acceleration* **is** positive *and speed error* **is** positive **then** *brake* b02

But using fuzzy logic if we control the throttle and brake of vehicle then it has some disadvantages i.e.it has only rule base, it does not train the output as referred to the input system.

Example:-For the valve of speed error 0.1 and the value of acceleration 0.01 the output is 0.2, For the valve of speed error 0.2 and the value of acceleration 0.012 the output is 0.4,then the fuzzy does not define for the valve of speed error 0.15 and the value of acceleration 0.015 the output is undefined. Hence we use a ANFIS(Adaptive-Network-Based Fuzzy Inference System) system to train the output with respect to all the values of input. Hence it will give more comfort to drive a vehicle.

3. THROTTLE AND BRAKE CONTROL USING ANFIS

For controlling a throttle and brake of vehicle using ANFIS system we design a general block diagram:-

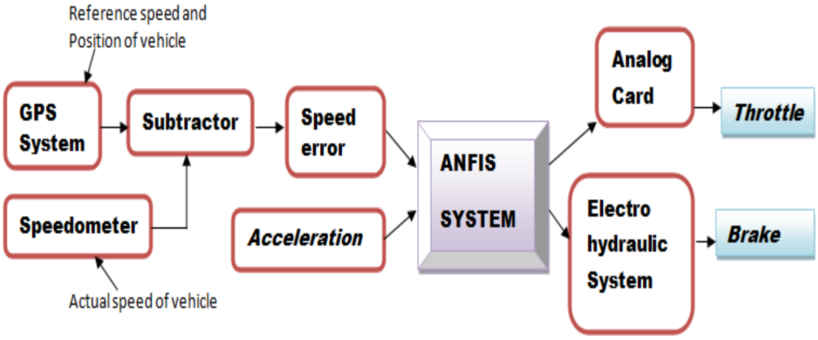

Fig j. General Block Diagram

When we use a ANFIS system to control the throttle and brake ,then this system gives more advantages to improve ITS (Intelligent Transport System).With the help of previous fuzzy control system which is used to control the throttle and brake we can design a ANFIS system. The rules of fuzzy system which is used in previous paper i.e if-then rule take a important role in our work [12]. We use a neural network hence we require an input data and output data.

We use two input signal for that ANFIS system i.e speed error and acceleration. The first input speed error consists of three membership function; negative value, null value and positive value of a signal. The second input acceleration consists of three membership function; negative value, null value and positive value of a signal. The type of membership function used for input signal is trapezoidal type. This system consists of two output signals. The first output signal throttle consists of nine membership functions i.e. t1,t2,t3,t4,t5,t6,t7,t8,t9 and second output brake signal also consists of nine membership functions i.e. b1,b2,b3,b4,b5,b6,b7,b8,b9.

For giving training to the ANFIS system we required a large number of input and output data. This data can be obtained from a very experienced driver. According to a large number of input and output data the number of error occurs at the output is decrease.

In our work a adaptive system is used that is if any error is occur at output side from the desired output then it will feedback to the input side to minimizing the error occur at the output side . the number of time the error is fed back to the input side is called as number of iteration or adaptive. The large number of iterations will give an error less system. This iteration is performing on the principle of back propagation.

4. RESULTS

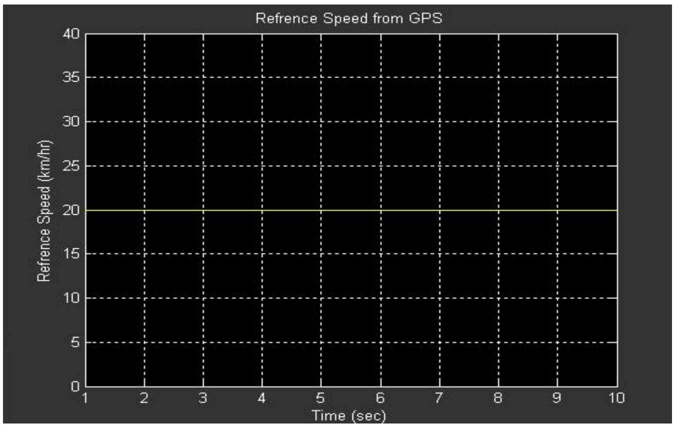

Fig k. Reference speed from GPS

Figure K shows the reference speed limit which would be received from the GPS system. The simulation result shown is obtained on MATLAB. From the figure, it can be seen that the reference speed is 20 km/hr.

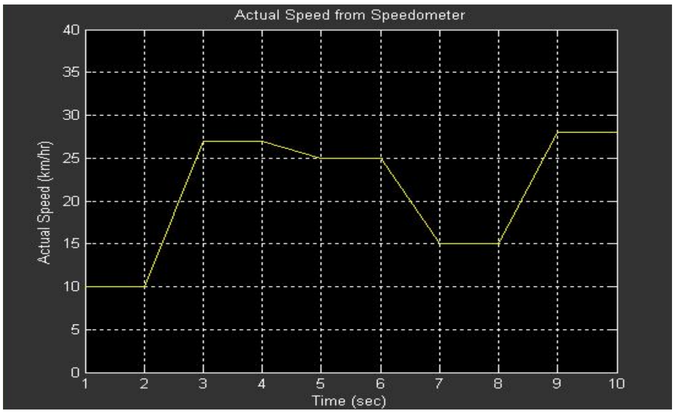

Fig l. Actual speed from speedometer

Figure l. shows the speed which is obtained from the speedometer. The simulation was performed on MATLAB. The graph shows the varying speed of the vehicle with time.

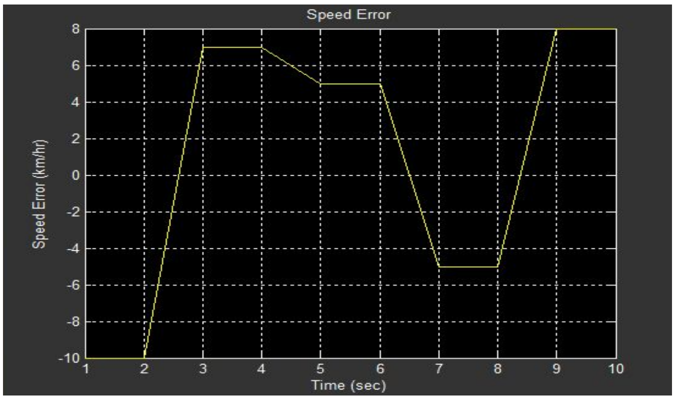

Fig m. Speed error

Figure m shows the speed error which was calculated considering the reference speed as shown in Fig K and the actual speed of the vehicle as shown in Fig l. The graph is obtained by performing the calculations on MATLAB.

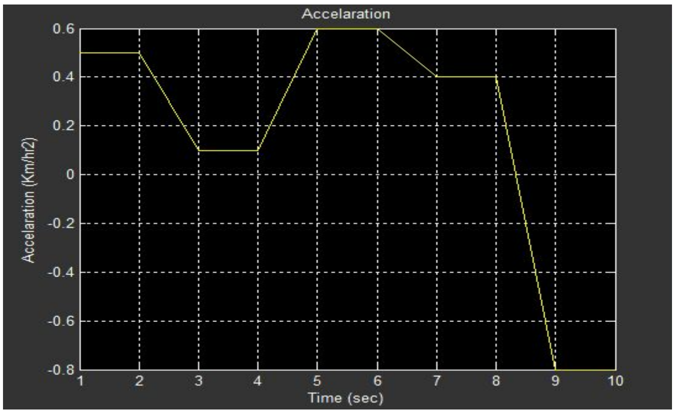

Fig n. Acceleration

Figure n shows the acceleration of the vehicle which can be obtained through the accelerometer. The above graph is the result of the simulation performed on MATLAB.

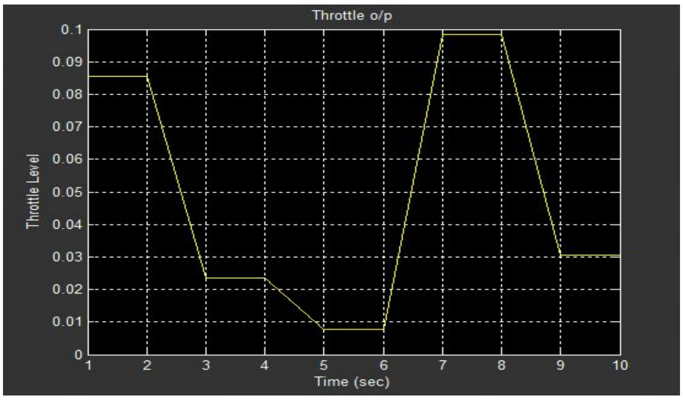

Fig p. Throttle output

Figure p. shows the throttle output of the vehicle which was calculated considering the speed error and the acceleration values of the vehicle. The ANFIS is trained by coding on MATLAB, such that for any speed error value and the acceleration value the throttle output would be varied. The ANFIS was fed with 500 samples of speed error, acceleration and the throttle output .As shown in the figure, for time period of 3 sec where the speed error was 7km/hr as shown in Fig m and the acceleration is 0.1 km/hr^2 as shown in Fig n, the throttle output is 0.025 as shown in Fig p. It implies that the throttle level is reduced as the speed error is exceeding the threshold value.

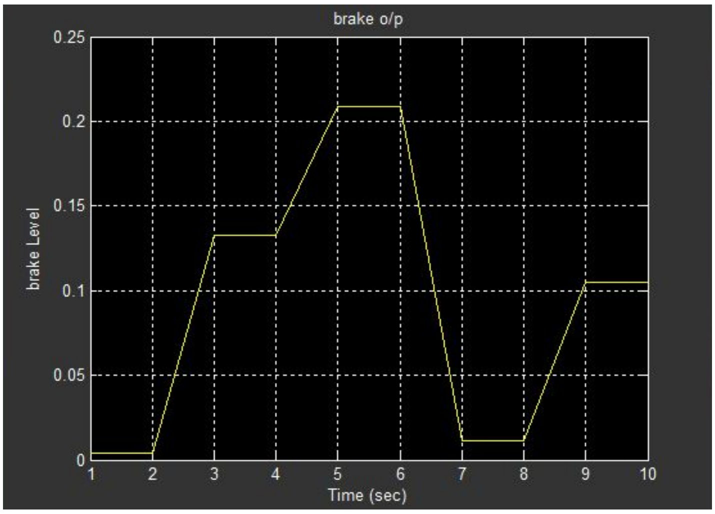

Fig q. Brake output

Figure q. shows the output for the brake. This result is obtained again by considering the acceleration and the speed error values on MATLAB. The ANFIS is trained by coding on MATLAB, such that for any speed error value and the acceleration value the brake output would be varied. The ANFIS was fed with 500 samples of speed error, acceleration and the brake output. E.g. At time period of 5 sec, the speed error value is 5 km/hr as shown in Fig m. And the acceleration value is 0.6 km/hr^2 as shown in Fig n, so the brake output is 0.21 as shown in Fig q, which implies that the brake level was increased as per the large speed error value.

5. Conclusion

The simulation results were obtained on MATLAB which shows that the throttle output and the brake output was varied as per the training of the ANFIS system which was provided with 500 samples of the speed error, acceleration, the throttle and the brake levels. As per the result obtained, it can be concluded that an intelligent ANFIS system is developed which is capable of varying the throttle and the brake levels as per the varying speed error and the acceleration values. It is desired that if the speed error and the acceleration is increased beyond the threshold limit, the throttle level has to be reduced and the brake level to be increased. This is obtained and verified from the simulation results. This further implies that the fuel efficiency is subsequently improved. This provides with such an automated system that the comfort of the driver is increased and the accidents can be controlled to a very large extent. This thus is expected to bring a revolution in the field of Intelligent Transportation System (ITS).

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