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# LabVIEW Based Intelligent Braking System for Automobile Application

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***Abstract:*** Increasing mobility in day-today life has led to the concern for the safety of automotives and human life. The development of intelligent driver assistance system is turning a significant element in the structure of future intelligent transportation system with the objective of reducing the no. of traffic accidents and their subsequent fatalities. The parameters derived from this intelligent system are based on passengers' safety and comfort.

In this context the intelligent braking system (IBS) is proposed by modifying the antilock braking system (ABS) technology. The simulation idea uses a switching action of IBS and ABS mechanism. It employs a self tuning Fuzzy Logic Controller with a Bang-Bang Controller and ultrasonic sensor. The sensing feature in IBS technology is conceived here in the purpose of instant braking in very near range. The Bang-Bang controller implements antilock braking capability during heavy braking conditions. Therefore the IBS arrangement in an automobile provides an extra degree of freedom towards the braking mechanism.

The above simulation model is formulated in graphical user interfacing software LabVIEW which yields a rapid control prototyping, real time simulation, in vehicle data logging and control and online noise, vibration and harshness testing towards the manufacturing field of the automobiles.

***Keywords:*** Intelligent driver assistance system, Intelligent braking system, Antilock braking system, LabVIEW.

## 1. INTRODUCTION

Intelligent driver assistance system is one of the most advanced and leading key factor for today's modern and innovated vehicles design. Basically driver assistance system is designed to support and affirm the driving process easier as well as takes the decision in a right sequenced manner. The above mentioned assistance systems such as adaptive cruise control, parking assistance system, antilock braking system, blind spot warning system and etc. are designed by considering the most advanced controller designing and various algorithm optimization, but these are pre-defined process whose algorithms and controller settings depend on the previously manipulated values. By using these traditional versions of assistance systems, we cannot modify the process online.

In this context we are proposing a different type of assistance system by combining the steering and braking mechanism. The best application of this steering assistance can be studied from lane changing and keeping technology [1-3] and this braking system can be analyzed from ABS technology [4-6]. Here the newly developed assistance system supports the driver in braking application case by monitoring the object on the road through long range ultrasonic sensor and presenting a relevant and timely information to the driver. Since the driver assistance system plays a vital role in vehicle safety and driving comfort, the intelligent braking system can be conceived as an important component for modern vehicle design. This advanced technology provides very significant information regarding the efficient driving with automatic braking system. Hence this advanced idea will offer a higher degree of safety and protection.

Since Fuzzy Logic Controller based system gives more efficient and better performance towards the real time simulation. So, it draws more attention and involvement from many research organization and

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automobile sectors. The developed Fuzzy Logic Controller is connected to three ultrasonic sensors, which generates the braking torque and steering angle and one simple on/off controller is used to activate ABS system.

The proposed work offers the operation of braking pedal on the wheel traction force in different road conditions by asserting safety and protection towards the driver and passengers. The main problem in this situation is coming from the influence of road surface specification and true design constraints on the optimal fuel consumption of the vehicle. Different forces are acting in different road profiles in longitudinal direction on the vehicle. They are categorized as the driving resistance forces which are listed below [7].

- Air drag resistance force ($F_d$)
- Rolling resistance force ($F_r$)
- Grade resistance force ($F_{gr}$)

The remaining part of the paper is organized as follows. Section II describes about the adopted methodology for developed system. Section III focuses on system description and analysis. Results are discussed in section IV and section V presents the conclusions and future work of the project.

## 2. METHODOLOGY

In this section the entire design idea and methodology are presented. The whole system consists of two parts. Among which one part is dedicated to the braking torque generation another one is taking care of ABS technology. Here the steering operation can be studied from defined assumptions described below.

- Two status LEDs are provided. One is for manual steering operation and another one is for automatic steering operation.
- When the steering is operated by driver then manual status will be indicated by one of the LED.
- In certain cases, when the developed technology will work, the manual operation of the steering will be locked and automatic steering action are going to be activated which is indicated by another status LED.

  In the similar fashion braking operation is designed by taking two different status LEDs to make it user friendly.

  Here passenger safety and comfort are derived from the acceleration and deceleration profile of the vehicle. Acceleration of the vehicle is limited to 2.5 $m/s^2$ increment and the deceleration is limited to –0.25 $m/s^2$ (When ABS is not activated) which are reported in literature [8 and 9]. In this ACC system we are deriving another constant speed controlling mode which is taken care by one anti windup PID controller.

- Constant speed control mode ($a_{cs}$)

  The desired acceleration of this mode is given by;

$$a_{cs} = t_p \,(V_{set} - V) + \frac{1}{t_i}\int (V_{set} - V) + t_d \,\frac{d}{dt}\,(V_{set} - V) \tag{1}$$

Here $t_p$, $t_i$ and $t_d$ are adjustable with time.

$V_{set}$ = Set speed

V = Current speed

It is required to limit the acceleration and deceleration to achieve the passengers comfort constraints.

The modified desired acceleration is given in equation (2).

$$a_{cs} = \begin{cases} 2.5, & a_{csd} > 2.5 \\ a_{csd}, & -0.25 < a_{csd} < 2.5 \\ -0.25, & a_{csd} < -0.25 \end{cases} \tag{2}$$

The total analysis is starting from the fixed Ultrasonic sensors which are placed in the front side of the car in three different positions i.e. left, middle and right. When the object is going to present in shorter range from car they will detect it and update the distance value from the car. That three distance values are taken into consideration in the design of Fuzzy Logic Controller. Depending on these object distances the controller is generating the braking torque and deciding the steering action automatically. After that the braking torque is given to the Bang Bang controller to activate ABS within desired slip value by calculating the relative slip from wheel speed and vehicle speed. This vehicle speed is given to the PID controller for safety acceleration purpose. The overall controller design and analysis is shown in Figure 1.

## 3. SYSTEM DESCRIPTION AND ANALYSIS

Here we are developing the ABS technology for short range application with obstacle detection since it gives an extra degree of safety and protection to vehicle and passengers through gradual braking system instead of quick action. Uncertain path braking system can be studied from the wheel free body diagram which is shown in Figure 2.

Form Figure 2 we can derive as per the following. The rotational dynamics can be designed by equation (3) and (4).

$$\mathrm{I}_w\omega_w = \mathrm{T}_{\mathrm{drive}} - \mathrm{T}_{\mathrm{loss}} - \mathrm{T}_{\mathrm{raction}} - \mathrm{T}_{\mathrm{brake}} \tag{3}$$

$$\mathrm{P}_x = \sum \mathrm{F}_\mathrm{X} = \mathrm{MV}_\mathrm{X} \tag{4}$$

Here $T_{drive}$ = Driving torque, $T_{loss}$ = Torque loss, $T_{raction}$ = Traction torque, $T_{brake}$ = Braking torque, $P_x$ = Momentum and $I_w$ = Moment of inertia of wheel.

Vehicle speed $V_X$ and wheel speed $\omega_w$ determine the slip ratio value $\lambda$ as in equation (5).

$$\lambda = \frac{\mathrm{V}_\mathrm{X} - \omega_w \mathrm{R}}{\max(\mathrm{V}_\mathrm{X}, \omega_w \mathrm{R})} \tag{5}$$

Here R = Radius of the wheel.

The max function in denominator of equation (3) gives the flexibility to calculate the slip for both acceleration and braking models. From this equation we can get the following information.

- $\lambda = 0$, i.e. vehicle velocity=wheel rolling speed. It means the absence of either engine torque or braking torque.
- $\lambda > 0$, i.e. wheel has positive finite rolling velocity and car has a greater finite forward velocity.
- $\lambda < 0$, i.e. car has finite forward velocity and wheel owns a greater equivalent positive rolling velocity.

So, at each extreme point i.e. at +1 and –1, the wheel is either ‘locked’ at zero speed or ‘spinning’ with vehicle at zero speed and when both the velocity is zero then slip ratio is mathematically undefined. Therefore zero is considered as slip ratio for simulation purpose.

The uncertain path braking system is designed here to monitor the operating conditions of the wheel carefully by taking the passengers safety and comfort into consideration.

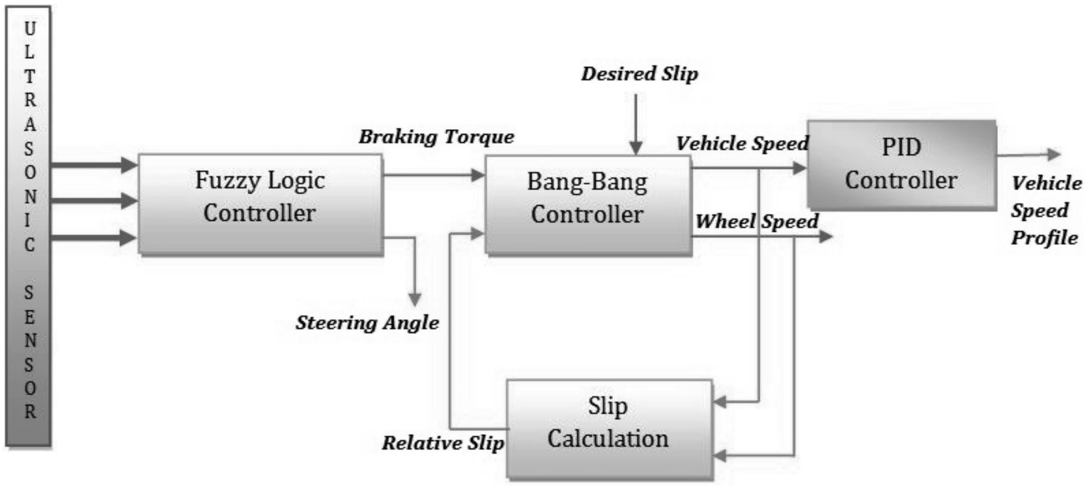


**Figure 1: Basic Block diagram of proposed model**

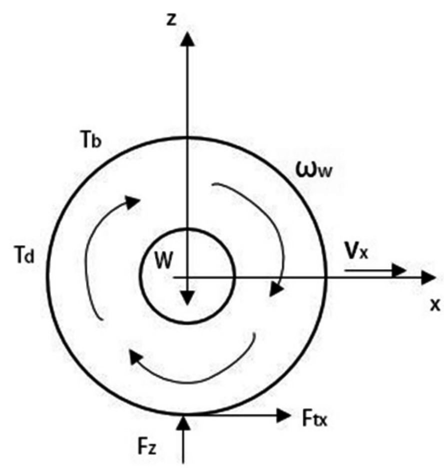


**Figure 2: Free body diagram of a simple wheel**

Depending on this operation and in the presence of object, the system applies the braking torque to keep the tires within a desired range of slip which is calculated from the static friction value. This mode of operation prevents the wheel from locking state and it maintains the steering stability of the vehicle. For this purpose a Bang-Bang controller is used which can be stated as the formula given below.

$$u(t) = \begin{cases} \mathrm{U}_1, e(t) > 0 \\ \mathrm{U}_2, e(t) < 0 \end{cases}$$

The constant speed controller is designed by taking anti-windup PID controller. This strategy prevents the integral term of the controller from accumulating errors when the controller output is saturated, i.e. the controller is unable to affect the controlled variable in a condition known as winding up. Here it is designed by taking windup time 1sec and saturation block (2.5 m/s$^2$ as upper limit and –0.25 m/s$^2$ as lower limit).

## 4. DISCUSSION OF RESULTS

The system is carried out in NI based LabVIEW software. The whole system starts to work after getting the information from three different ultrasonic sensors. The developed Fuzzy Logic Controller input and output variables are stated below.

Input variables {left, center and right}.

Output variables {Brake action and Steering action}.

The input and output linguistic variables are shown in Figure 3. The input linguistic variables are divided into 3 parts. i.e. close (0 to 1 m), medium (0.6 to 1.5 m) and Far (1.2 to 2.5 m). Similarly steering action is divided as neg_large, neg_med, neg_small, zero, pos_small, pos_med and pos_large in the limit of -30 deg to 30 deg and the braking action is divided as bl1, bl2, bl3, bl4, bl5 and bl6 within the limit of 50% to 100%.This linguistic variable function is shown in Figure 3, 4 and 5.

Some of the designed rule base and the vehicle parameters are shown in Table 1 and 2 respectively. For the design of the ABS controller we can use "dead band" to improve the noise rejection and the response of the controller. A general designing assumption plotting data are shown in Figure 6, 7 and 8 with respect to time as per the available information in Table II.

The developed system mainly focuses on 3 points.

- Application of Braking system in short range presence of objects.
- ABS technology is revised to intelligent braking system.
- Speed profile is designed by considering safety accelerations and decelerations.

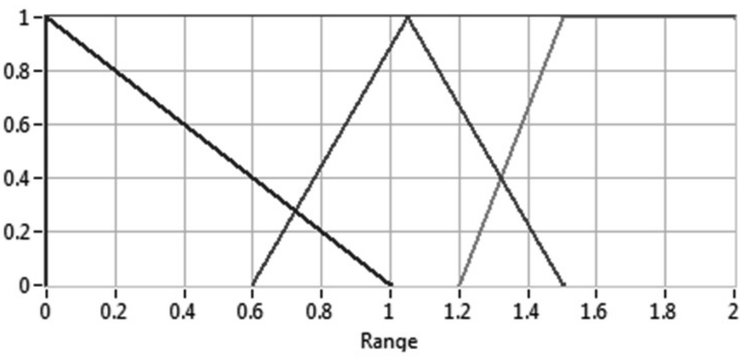


**Figure 3: Membership functions of input variables**

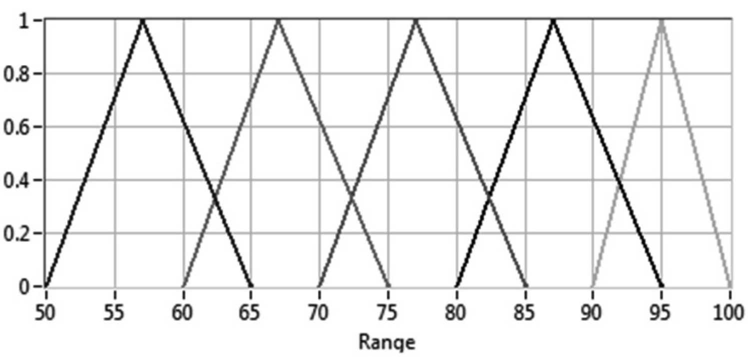


**Figure 4: Membership functions of braking action**

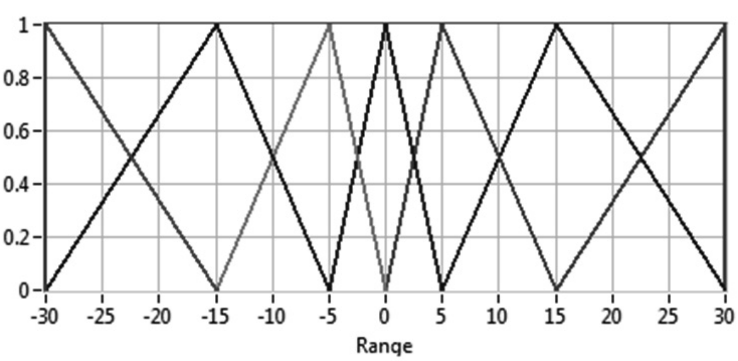


**Figure 5: Membership functions of steering actions**

**Table 1**
**Fuzzy Rule Base**

| *Ultrasonic sensor position* | | | *Action* | |
|---|---|---|---|---|
| *Left* | *Center* | *Right* | *Brake* | *Steering* |
| Far | Far | Far | Bl1 | PM |
| Far | Far | Medium | Bl2 | NC |
| Far | Far | Close | Bl3 | NC |
| Far | Medium | Far | Bl3 | PM |
| Far | Medium | Medium | Bl4 | NM |
| Far | Medium | Close | Bl4 | NM |
| Medium | Far | Far | Bl2 | PC |
| Close | Far | Close | Bl5 | ZE |
| Medium | Close | Medium | Bl5 | ZE |

**Table 2**
**Simulation Parameters For Braking System Design**

| *Name* | *Value* | *Unit* |
|---|---|---|
| Wheel mass | 50 | kg |
| Moment of inertia | 5 | $Kg/m^2$ |
| Driving torque | 0 | N-m |
| g | 9.81 | $m/s^2$ |
| Wheel radius | 1.25 | M |
| Mu Factor | 1 | ----- |
| Desired slip | -0.15 | ----- |
| Initial Vehicle speed | 50 | Km/hr |
| Controller gain | 1.2 | ------ |
| Dead band | 0.016 | ------- |

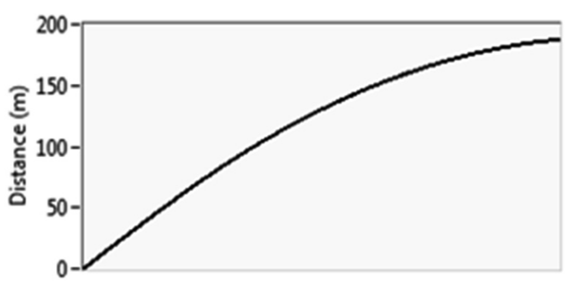


**Figure 6: Stopping distance before the object**

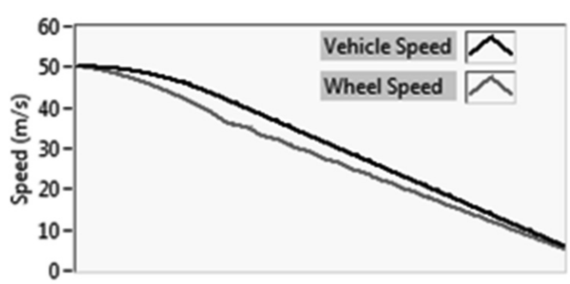


**Figure 7: Speed profile for vehicle and wheel**

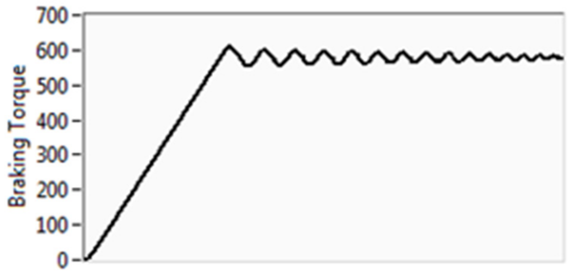


**Figure 8: Braking torque of the mechanism**

## 5. CONCLUSIONS AND FUTURE WORK

In this paper a special type of intelligent braking mechanism is developed by considering different positions of the object on the road. This kind of technology can be applied for the short range applications which will add an additional flexibility to the antilock braking system. The primary goal of this project is to generate the necessary amount of braking torque and to decide the fixed angle of rotation of steering wheel in different conditions of the presence of object to keep the vehicle in safety speed mode without the prior knowledge of the driver. By this developed scheme we can avoid the accidents mainly caused from short range presence of objects in uncertain road conditions.

For simulation and validation process we are using graphical system design software LabVIEW for better real time performance and easy data acquisition process. After that in this volatile market LabVIEW is becoming a powerful tool for the automotive industry which can offer the rapid control prototyping, hardware in-loop simulation, real time simulation, diverse I/O, test cell measurement and control, automotive end of line testing, in vehicle data logging and control and online noise, vibration and harshness test to the vehicle.

This work may be extended to the generation of driving torque for the vehicle from another Fuzzy Logic Controller by considering the same presence of objects, different action of supporting and opposing forces and uncertain road profiles. Hence this driving torque and braking torque will combinely help the ABS to operate which will maintain more safety than previous one.

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