Intelligent Car Braking System with Collision Avoidance and ABS

Dhivya P.
M.E. Embedded System Technologies
KSR Institute for Engineering and Technology
Tiruchengode, Tamilnadu, India

Murugesan A.
Assistant Professor, Department of EEE
KSR Institute for Engineering and Technology
Tiruchengode, Tamilnadu, India

ABSTRACT
This paper provides an efficient way to design an automatic car braking system using Fuzzy Logic. The system could avoid accidents caused by the delays in driver reaction times at critical situations. The proposed Fuzzy Logic Controller is able to brake a car when the car approaches for an obstacle in the very near range. Collision avoidance is achieved by steering the car if the obstacle is in the tolerable range and hence there is no necessity to apply the brakes. Another FLC (which is cascaded with the first FLC for collision avoidance) implements the Anti-lock Braking capability during heavy braking condition. Thus the system is made intelligent since it could take decisions automatically depending upon the inputs from ultrasonic sensors. A simulative study is done using MATLAB and LabVIEW software. The results obtained by the simulation model are compared with the existing system and the proposed model conveys a satisfactory result which has high consumer acceptance. ATMega controller is used for implementation of the proposed system.

General Terms
Ultrasonic Sensor, Fuzzy Logic, Mamdani fuzzy logic controller.

Keywords
Collision Avoidance, Anti-lock Braking System (ABS), Slip Ratio, Simulation Interface Toolkit (SIT).

1. INTRODUCTION
The number of automobile users is increasing day by day. At the same time, traffic congestion has become a worldwide problem. This problem is mainly due to human driving which involves reaction time delays and judgment errors that may affect traffic flow and cause accidents. Engineers in the automotive industry put a lot of effort in devising systems which ensure safety in road vehicles. Even with all the advancements in vehicle safety technology, the number of people killed in auto accidents continues to rise. Close to 1.2 million people die each year on the world's roads and that number is expected to rise by 65 percent by the year 2020, says a report by World Health Organization (WHO) and the World Bank.

Braking system is the most important system in a car. Generally, a car brake system is operated manually as the driver pushes the brake pedal. If the brake fails, the result can be disastrous. Countless rear-ending automobile accidents could have been prevented or at least reduced in damage cost if the rear-ending driver had applied a sufficient amount of brake pressure at the right time. Unfortunately, the time required by the driver to understand potential accident situations, compounded with driver's delayed reaction times in applying the brakes, usually causes a lag between the identification of a potential accident situation and the execution of the corrective actions that will prevent the accident. Hence, in such emergency situations an efficient control mechanism has to be employed to avoid accidents.

Therefore, by automating the task of assessing the situation and deciding the correct amount of brake pressure, we could prevent numerous accidents. By that means, the car brake itself should have a good software system to assist a driver along the road. This would significantly decrease the amount of property and monetary loss due to accident damage, and it could save lives.

There are two issues related to the design of intelligent braking system. Collision Avoidance (CA) is a difficult and challenging operation for driving autonomous vehicles. The challenge in designing a Collision Avoidance system is in balancing the effectiveness of avoiding collisions versus the risk of false alarms. False alarms are extremely critical, because they may lead to serious consequences. This maneuver is used in a critical situation by braking and/or steering the car as long as the accident is still avoidable. Anti-lock braking is another issue in designing an efficient braking system in automobiles. Conventionally, in automobiles equipped with ABS, it is a part of the engine control unit and prevents the locking up of wheels. Hence, applying fuzzy logic to intelligent control seems to be an appropriate way to achieve this human behavior, because driver's experience can be transformed easily into rules and any kind of non-linearities can be easily tackled.

The organization of this paper is as follows. Section 2 gives an overview of collision avoidance and ABS. Section 3 discusses the existing scenario of car braking system. Section 4 explains the proposed technique which describes the implementation of the system in MATLAB and LabVIEW. Section 5 shows the results of simulation and comparison of results with the existing techniques. Section 6 concludes the work done on intelligent car braking system.

2. OVERVIEW
Automatic braking is a technology for automobiles that sense an imminent collision with another vehicle, person or obstacle; and applies the brake to slow-down the vehicle without any driver input. Sensors to detect other vehicles or obstacles can include radar, video, infrared, ultrasonic or other technologies.

2.1 Collision Avoidance
Automatic braking by the system after sensing an obstacle can be executed in two modes: In collision avoidance, the collision is avoided by the automatic braking, but the driver

will not be warned in this type of system. In collision mitigation system, the sensors detect the possibility of collision but will not take immediate action. A warning will be sent to the driver in the form of a signal or a voice message. The decision to apply brakes is left with the driver and the brakes are applied automatically only in the most emergency situations.

A collision avoidance system (CAS) should involve, at least, the following three main parts: 1) object detection; 2) decision making; and 3) actuation [1]. Object detection relates to perception tasks that analyze the environment information obtained by one or more sensors. A decision-making system interprets these estimates and makes a decision on when and how collisions can be avoided. The complexity of this stage depends on the specific traffic situation. Finally, one actuation system adapts the target commands generated by the previous stage and transforms these commands to low-level control signals needed by the respective actuators: 1) throttle; 2) brake; and 3) steering. The generated signals have to take the corresponding actions to avoid the collision.

2.2 Anti-Lock Braking System

An anti-lock breaking system is a system used for the safety of motor vehicles. This system allows the wheels of a motor vehicle to maintain frictional contact with the road surface according to the inputs by the driver, while the braking prevents the wheels from locking up [2]. This locking up of wheels occurs when the rotation of the wheels comes to a halt suddenly. The system should be designed in such a way that it prevents the wheels to stop rotating instantly which could cause the vehicle to skid and the driver could lose control of the vehicle. It increases the breaking distance when the road surface is loose like in case of a snow clad surface or if the road has gravel on it. On the other hand the system reduces the breaking distance when the surface is dry or slippery like in case of a wet surface [3]. ABS control is a highly nonlinear control problem due to the complicated relationship between friction and slip. The features of Anti-lock Braking System are as follows:

- Reduction in stopping distance
- Vehicle stability
- Vehicle steerability

Slip ratio is a means of calculating and expressing the locking status of a wheel and is vital to the effectiveness of any anti-lock braking system. When a vehicle is being driven along a road in a straight line its wheels rotate at virtually identical speeds. The vehicle's body also travels along the road at this same speed. When the driver applies the brakes in order to slow the vehicle, the speed of the wheels becomes slightly slower than the speed of the body, which is travelling along under its own inertia. This difference in speed is expressed as a percentage, and is called 'slip ratio'.

$$\text{Slip Ratio\%} = \frac{\text{Vehicle Speed} - \text{Wheel Speed}}{\text{Vehicle Speed}} * 100\% \qquad (1)$$

Slip ratio is vital for maintaining stability and steerability of the vehicle. It can be calculated from vehicle speed and wheel speed as given in (1) and it is desirable to maintain the desired slip ratio for the given road surface during heavy braking. The ideal slip ratio for maximum deceleration is 10 to 30% to maintain high friction.

3. EXISTING SCENARIO

The existing system of automatic car braking system uses the fuzzy logic to apply the brake when the position of the obstacle is near and the velocity of the vehicle is high. It uses one ultrasonic sensor placed infront of the vehicle to calculate the distance of the obstacle from the vehicle. This scheme does not consider the obstacles by the side of the vehicle and has no way of steering the vehicle when the obstacle is out of collision range, which could be avoided. Other existing system of automatic car braking system has diver assistance capabilities. In these systems, the driver will be assisted to apply the brake when the driver fails to act in time [4]. This system will come into play only when the critical situation arises. This scheme is not acceptable since only driver assistance is provided and no intelligent action is taken even under critical situations. This may cause accidents when the driver fails to react in time as soon as the assistance is provided.

Considering the existing system for collision avoidance, it uses two ultrasonic detectors to find the distance of the obstacle from the vehicle [5]. The two sensors will be at the sides of the vehicle. The system uses a total of nine rules to avoid obstacles at the sides which will not be so very accurate since the obstacle at every possible situation has to be taken into account. Such schemes will be suitable only for indoor applications like robot or wheelchair to avoid collisions [6]. However for outdoor applications, such collision avoidance schemes are not sufficient and have to be still more accurate.

In automobile industry, almost all sophisticated vehicles are equipped with ABS. This system forms a part of the control unit of the vehicle, which uses wheel speed sensors to anticipate the condition of wheel lock up. This condition is determined when any of the wheels in the vehicle is identified to rotate slowly when compared to other wheels. The existing system of Anti-lock Braking System uses bang-bang controller. Some manufacturers use fuzzy logic to adjust the values of PID controller which will prevent the locking up of wheels [7]. The system will provide smooth performance if it is modelled completely using fuzzy logic which could best represent the natural behavior. The existing system is complex since it has to discriminate between reduction in wheel speed while steering the vehicle and reduction in wheel speed while stopping the vehicle. Hence the system can be made simple by activating the ABS only during high braking conditions.

4. PROPOSED TECHNIQUE

The block diagram of the proposed system with two cascaded Mamdani fuzzy logic controllers for collision avoidance and antilock braking system is depicted in figure 1. Mamdani fuzzy controller has been proved to perform well when compared to Sugeno-type fuzzy logic controller [8]. The proposed system of intelligent braking system uses two Fuzzy Logic Controllers (FLCs) for taking decision i.e., one controller decides upon whether to stop the car or to steer the car to a particular angle to avoid collision with the obstacle in its path. It has two outputs: force of brake and steering angle. The force of the brake is taken as the activation input for the second fuzzy logic controller. This controller will decide the control value for varying the brake pressure to regulate the wheel speed and prevents it from locking at heavy braking conditions. Thus, the system is made intelligent by employing fuzzy logic to take decisions without human intervention.

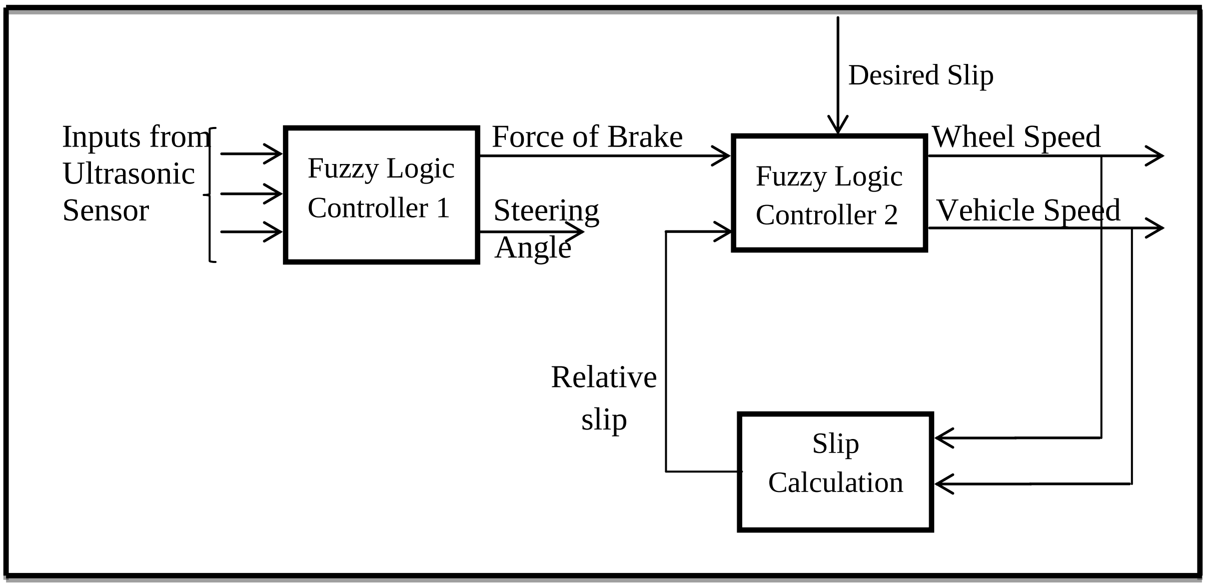

Figure 1: Block diagram of the proposed system

4.1 Overall Simulink Model

The simulation is carried-out in MATLAB/Simulink and the model is shown in figure 2. The FLC-1 uses the inputs from three ultrasonic sensors namely, Left Sensor (LS), Middle Sensor (MS) and Right Sensor (RS). The range of the obstacle from the car is categorized as near, medium and far. Hence, a total of twenty-seven rules have been formulated using fuzzy logic. The output of this controller is the force of the brake and steering angle. Car steering is controlled as long as the obstacle is in the range that could be avoided without any collision. Hence, collision avoidance is achieved using FLC-1.

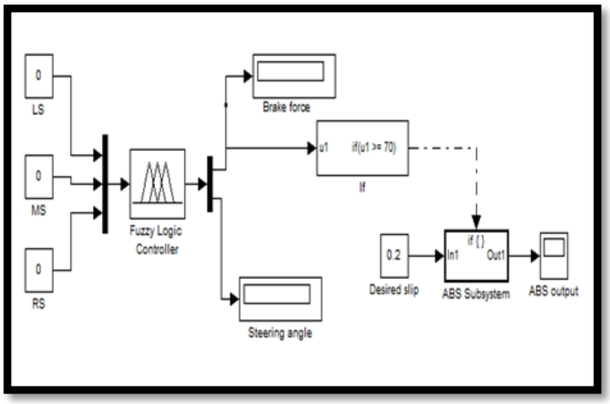

Figure 2: Simulink model for the proposed system

FLC-2 is cascaded with FLC-1 and it is a part of the ABS subsystem to achieve the anti-lock braking capability. The force of the brake output from the first controller is used as the activation input. This means that, ABS will come into play only when the force of the brake applied is high. The desired slip (which is 20% for dry road condition) is the reference input. From the vehicle dynamics, the vehicle speed and the wheel speed is devised. From these values the actual slip is calculated by using the formula given in (1). The difference between the actual and the desire slip (error, e) and the rate of change of error (ec) is taken as the input to the FLC-2. Both e and ec have three membership functions namely, positive, zero and negative. Hence, a total of nine rules are formulated. These rules will decide upon the amount of brake pressure to be applied to regulate the wheel speed to match with the vehicle speed. The ABS is a closed loop control system which regulates the wheel speed based on the slip feedback which is compared with the desired slip and runs until the vehicle stops. This ensures the stability of the car since wheel locking is prevented.

4.2 ABS Subsystem

ABS subsystem consists of blocks and subsystem that gives the mathematical model for the vehicle behavior and the slip-friction characteristics of the road surface on which the vehicle is moving. The vehicle speed after applying the brake is calculated from the braking force and deceleration of the vehicle. The formula for calculating the braking force from the mass and friction value is given by (2),

$$\text{Braking Force (F)} = \frac{\mu * m * g}{4} \quad (2)$$

On applying the braking force, the vehicle speed reduces i.e., it decelerates. The angular speed of the vehicle is calculated by dividing the linear speed of the vehicle by the wheel radius. The angular wheel speed is calculated from the mathematical model of tire, which is given in (3),

$$\omega = \int \frac{(F * a) - T_b}{J} \quad (3)$$

T_b and J represent the braking torque and inertia of the wheel respectively. The wheel speed calculated from the above expression has to be regulated to prevent locking-up of wheels. Hence, the FLC-2 is implemented in the wheel speed subsystem. The output of FLC-2 is the control value which varies the brake pressure and maintains the wheel speed relative to the vehicle speed. With the subsystem for wheel speed, the Simulink model for ABS can be derived as shown in figure 3. The ‘Ctrl’ block represents the control for anti-lock braking system, which is the condition which decides whether the feedback is included in the system or not. If this control value is 0, then it means that the slip feedback is not included in the system and hence the wheels stops suddenly (i.e., it locks).

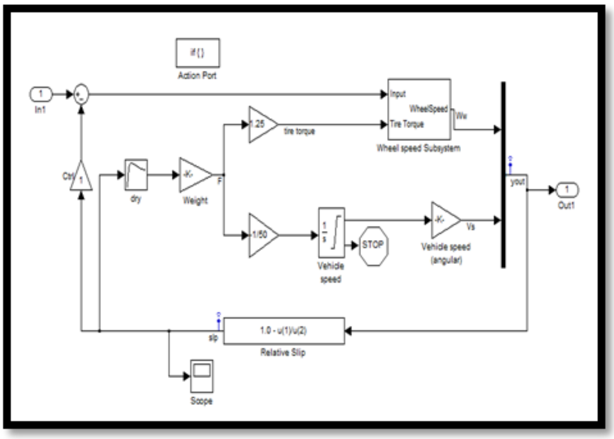

Figure 3: ABS Subsystem

The above model was created using MATLAB/Simulink [9]. Simulink is an add-on toolkit for MATLAB, and it provides a graphical environment for the design and interactive execution of dynamic system models. A method is needed to allow a Simulink model to perform data acquisition [10] [11]. Simulation Interface Toolkit (SIT) of LABVIEW performs this task. The Simulation Interface Toolkit (SIT) provides a way to create a LabVIEW user interface that can be used to interact with a Simulink model. With a LabVIEW user interface, the model parameters can be manipulated and the output data of the Simulink model can be viewed immediately. When MATLAB is launched, the Simulation Interface Toolkit (SIT) Server is also started, which enables LabVIEW and MATLAB to communicate with each other. The SIT automatically generates LabVIEW code to interface with a Simulink model and the block diagram generated is shown in figure 4.

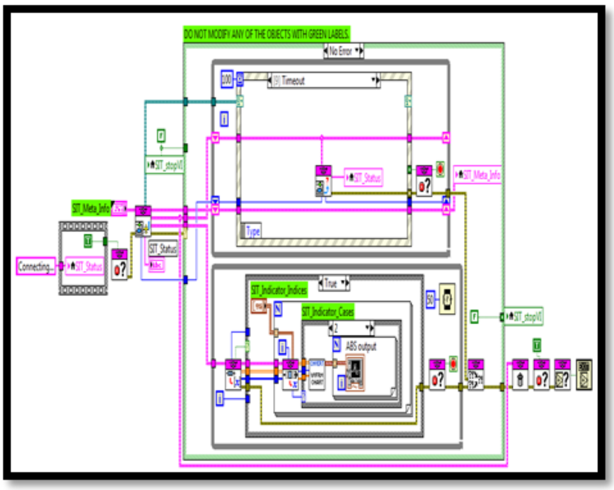

Figure 4: LabVIEW Block Diagram

5. RESULTS

The results of the simulation during various readings of the sensors are shown in following figures. The sample output of the intelligent car braking system when the obstacle is in the range of avoidance is shown in the figure 5. In such situations the ABS will not be activated since the force of the brake applied is low or medium and hence there is no chance of wheel lock up and the vehicle steering could be controlled.

When the car has to take short left or short right turn the brake force is low. On the otherhand, when the car has to take long left or long right turn the medium force of the brake should be applied.

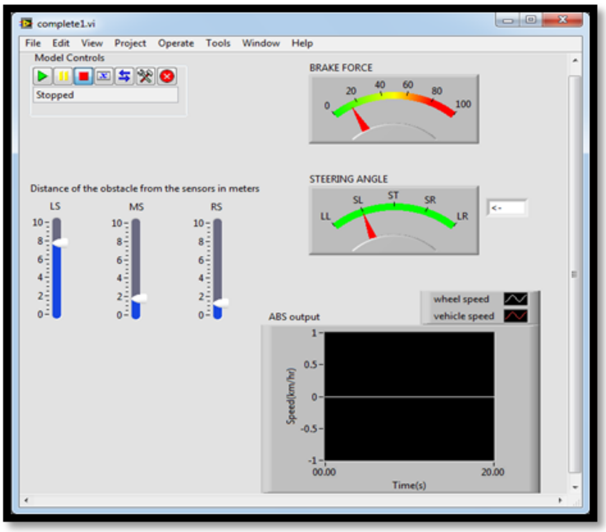

Figure 5: Sample Output for Collision Avoidance

Figure 6 below shows the output of the system when the obstacle is identified to be near in all the three sensors. In this case, the vehicle could not be steered to the right or left since it could collide with the obstacle by the side of the car and hence high force of brake is applied to stop the car. This is the only situation where heavy braking condition arises. Due to this heavy braking condition the ABS is activated to prevent wheel lockup.

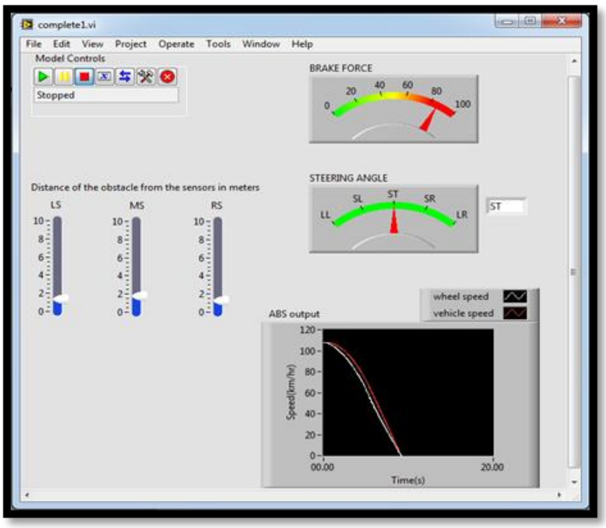

Figure 6: Output of the System during Heavy Braking

From the above figure we can say that when the ABS is activated, the wheel speed is not reduced to zero suddenly i.e., the wheels are not locked. Instead, the wheel speed is regulated by the ABS to match with the vehicle speed and hence the car will not skid and stability is maintained.

Table 1 shows the comparison of the proposed fuzzy logic controller and the controller used in the existing system of automatic car braking system.

Table 1. Comparison of existing and proposed system

Parameters	Existing System	Proposed System
Stopping Time (s)	14	6
Braking Deceleration (m/s^2)	-5.632	-8.584
Braking Torque (Nm^2)	476.6	505.3

6. CONCLUSION

The existing system used Bang-bang or PID controller in the electronic control unit of the car to prevent the locking up of wheels [12]. The proposed system uses Fuzzy Logic to design the controller and hence the system is more reliable than the existing system and has wide consumer acceptance. From the table 1, it can be summarized that the proposed system has high values of braking deceleration compared to that of the existing Bang-bang controller. Hence, the vehicle could be stopped in a short distance compared to the existing system. The simulation results shows that the curve settles down smoothly and the car will not experience any jerks at high braking conditions in contrast to the existing system.

7. REFERENCES

[1] David Fernandez Liorca, Vicente Milanes, Ignacio Parra Alonso and Miguel Gavilan (2011) 'Autonomous pedestrian collision avoidance using a fuzzy steering controller', IEEE Transactions on Intelligent Transportation Systems, Vol.12, No.2, pp.390-401.

[2] Chuting Mi, Hui Lin and Yi Zhang (2009) 'Iterative learning control of antilock braking of electric and hybrid vehicle', IEEE Transactions on Vehicular Technology, Vol. 54, No. 2, pp.486-494.

[3] Ayman A. Aly (2010) 'Intelligent fuzzy control for anti-lock braking system with road-surfaces identifier', Proceedings of the IEEE International Conference on Mechatronics, pp.699-705.

[4] Shrey Modi, Yingzi Lin, Zhang W.J and Yang G.S (2012) 'A driver-automation system for brake assistance in intelligent vehicles', Proceedings of the 10th IEEE International Conference on Industrial Informatics, pp.446-451.

[5] Vijayakumar Ch, Pavan Kumar N, Prathiba J and Vijay Kumar K (2013) 'Sensors based automated wheel chair', Proceedings of the IEEE International Conference on Green Computing, Communications and Conservation of Energy, pp.439-443.

[6] Hasan K. M, Sabina Khan, Sameen Javaid and Asif Raza (2010) 'A low cost microcontroller implementation of fuzzy logic based hurdle avoidance controller for a mobile robot', Proceedings of the 3rd IEEE International Conference on Computer Science and Information Technology, pp.480-485.

[7] Bo Lu, Yu Wang, Jing-Jing Wu and Jin-Ping Li (2010) 'Anti-Lock braking system design based on improved fuzzy PID control', Proceedings of the IEEE International Conference on Natural Computation, pp.62-65.

[8] Ghulam Abbas and Muhammad Usmah Asad (2011) 'Comparative analysis of zero-order sugeno and mamdani fuzzy logic controllers for obstacle avoidance behavior in mobile robot navigation', Proceedings of the IEEE International Conference on Current Trends in Information Technology, pp.113-119.

[9] Hui Lin and Channxue Song (2011) 'Design of a fuzzy logic controller for abs of electric vehicle based on amesim and simulink', Proceedings of the IEEE International Conference on Transportation, Mechanical and Electrical Engineering, pp.779-782.

[10] Izzuddin Muhammad Iqbal, Muhamad Hariz Rosli, Mohd Azlan Abu and Zainudin Kornain (2012) 'Automated car braking system using neural network system via labview environment', Proceedings of the IEEE International Conference on Open Systems, pp.1-6.

[11] Kai Zhou, Xudong Wang, Chao Zhang and Jian Liu (2010) 'Data acquisition system based on labview for abs dynamic simulation test stand', Proceedings of the IEEE International Conference on Information and Automation, pp.2214-2218.

[12] Samuel John and Jimoh O. Pedro (2013) 'A comparative study of two control schemes for anti-lock braking systems', Proceedings of the 9th IEEE Asian Control Conference, pp.1-6.