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Design and Development of a Prototype for a Pascal's Law & IoT applied Automatic Hydraulic Braking System

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Abstract

The widespread adoption of autonomous vehicles continues to increase along with various scientific and technological advancements, and this is necessitating the application of essential accident prevention measures. This research presents the design and development of an innovative hydraulic braking system utilizing readily available components and materials. The Pascal's law of pressure is very applicable in modern hydraulic braking mechanisms. The system employs an ultrasonic sensor, a repurposed disk, a motor, and a solenoid lock controlled by a relay to create an effective braking mechanism. The primary objective of this research is to demonstrate the feasibility of constructing a functional braking system based on Pascal's law of pressure, using locally sourced materials, catering to resource-constrained environments. The proposed hydraulic braking system functions as follows: when the ultrasonic sensor detects an object within its proximity (approximately 20 centimeters), it triggers the relay, which activates the solenoid lock. The solenoid lock's action initiates the movement of a syringe compressor, exerting pressure on the hydraulic fluid. This pressure is then transmitted to the repurposed DVD (Digital Versatile Disk), which serves as the braking element. As the disk is pressed against a surface, the resulting friction decelerates the system, effectively applying the brake. Finally, data is evaluated in the IoT (Internet of Things) platform ThingSpeak to identify safe and harmful states.

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1. Introduction

An autonomous vehicle system is the one which doesn't need any human support for running on the roads. The autonomous cars like that of Tesla's are very popular due to their vast range of capabilities. This proposed low-cost prototype is based on the hydraulic braking system model that effectively, relies upon the ultrasonic sensor-based vehicle braking. The utilization of commonplace components such as the ultrasonic sensor, DVD disk, and motor, along with the integration of a solenoid lock for precise control, showcases a novel approach to constructing a braking system. The use of locally available materials like a wooden frame enhances the system's affordability and adaptability, rendering it suitable for regions with limited access to advanced technologies. The research discusses the design considerations, component selection, system integration, and testing procedures, culminating in a functional hydraulic braking system prototype.

2. Literature Review

The goal of the research was to create a highly accurate brake light recognition system for preventing or avoiding accidents involving rear-end collisions. The datasets are trained and validated using the YOLOv3 algorithm, and the datasets are annotated using the Pascal VOC and Labelling tools. According to tests, the system has a detection accuracy range of 40.0553% to 84.74234%. This demonstrates that the algorithm can recognize brake lights to avoid rear-end crashes [1].

The creation and construction of an electro-mechanical parking brake (EMPB) system are the subjects of this subject of this research. Mechanical device hand brake systems, also known as brake by-wire, swap out conventional parking braking systems for an electrical component system. This is accomplished by substituting electrically motor-driven devices for standard linkages. High performance electrical motors and automobile management, which are under the control of an electronic control unit (ECU), immediately provide braking force at each wheel. The conventional handbrake is replaced by the electronic handbrake. Within the centre console is a switch that controls it [2].

A transmitter and a receiver are part of an ultrasonic system that is positioned in front of the vehicle. When an obstacle is recognized, the ultrasonic waves are always being emitted by the ultrasonic emitter and are reflected back to the receiver, which then picks up the signal. Based on the object's distance, the signal from the reflected wave is sent to the Arduino Nano, which activates the buzzer or the brakes. Solenoid valves are utilized to activate the brakes. A solenoid valve is controlled by an electrical signal and actuates brakes pneumatically [3].

In this technology, the front area of the car has an ultrasonic wave emitter that generates ultrasonic waves. Additionally, a receiver for ultrasonic waves that are reflected off the front of the car is positioned there. The microprocessor uses the detected pulse to regulate the vehicle's speed. Today, with the development of many IC engine types, speed is a crucial aspect that frequently results in disastrous events. So, by implementing an ultrasonic braking system, the number of fatalities in traffic accidents can be lowered [4].

The current effort develops and tests a test setup for the use of ultrasonic sensors in safety systems that regulate a vehicle's speed. An ultrasonic wave emitter installed on the front portion of a car produces and emits ultrasonic waves frontward across a predetermined distance as part of an intelligent mechatronic system. Additionally, a reflecting ultrasonic wave signal is operationally received by an ultrasonic receiver that is mounted to the front of the car. The distance between the obstruction and the vehicle is determined by the reflected wave (detected pulse). Then, a microcontroller is employed to regulate the vehicle's speed based on the information from the detection pulses in order to depress the brake pedal and apply the brakes to the automobile firmly for safety reasons [5].

3. Proposed System

The proposed method utilizes an ultrasonic sensor to detect obstacles, and if any are found, braking is applied by activating a syringe with a solenoid lock, creating hydraulic control to force the disk to halt, which is assumed to be a tire. To apply brakes to the disk, the piston is actuated using the solenoid lock and its associated syringe piston. The proposed concept makes use of extremely basic, readily available materials to build a low-cost prototype. The data of distance is rapidly sent to cloud IoT platform ThingSpeak. The cloud platform is used to monitor the vehicle distance and safety which is monitored with the help of a lamp indicator on cloud for safe & unsafe condition, indicated by high or low relay states. Analysing the safe and unsafe states of the braking system in the context of a real-world scenario is the goal of ThingSpeak monitoring.

3.1. Algorithm and Flowchart

System Algorithm

1. Initialize the Components:

Set up the Esp32, ultrasonic sensor, relay, solenoid lock, and hydraulic system components.

2. Sensor Reading and Processing:

Read distance data from the ultrasonic sensor.

Store the distance value in a variable.

3. Check Distance:

If the distance is less than 20 cm (obstacle detected):

Proceed to the next steps.

Else:

Skip the brake activation process.

Loop back to reading the sensor.

4. Activate Relay: Trigger the relay to unlock the solenoid lock.

5. Hydraulic System Activation:As the solenoid lock releases:

Push the syringe plunger to create hydraulic pressure.

Transmit the pressure to the brake piston.

6. Brake Application:The brake piston moves and applies force to the CD disk (braking action).

7. Release Brake: Deactivate the solenoid lock to release the pressure on the hydraulic system.

8. Sensor Reset: Wait for the obstacle to move away or system conditions to change.

9**.** Update Value

Update the distance of value on Cloud thingspeak IoT platform to monitor the status of system

10. Loop: Return to reading the ultrasonic sensor data.

Repeat the process from step 2.

11 End: Stop the system or keep it in a standby state as needed.

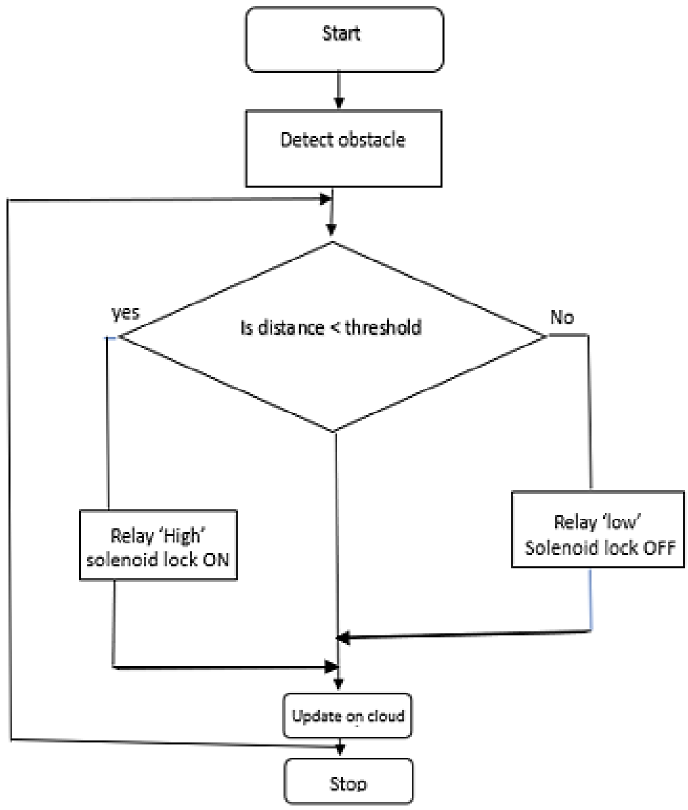

Figure 1. System Flowchart

3.2. Circuit Diagram

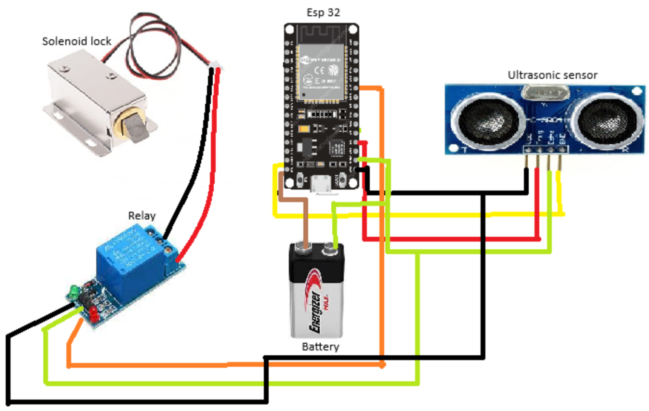

Figure 2. System Circuit Diagram

3.3. Pascal's Law in Hydraulic Braking Mechanics

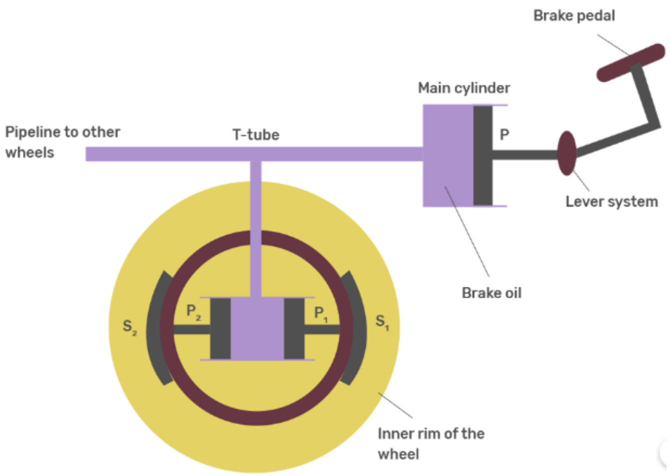

Figure 3. Pascal's Law Application in Hydraulic System [17]

A key component in the functionality of hydraulic braking systems is Pascal's law. The master cylinder experiences force when a driver depresses the brake pedal, which starts a series of events controlled by Pascal's law. The brake calipers or wheel cylinders at each wheel receive an even distribution of the pressure produced within the master cylinder via the brake fluid [17]. Here, the brake shoes or pads are forced to come into contact with the rotor or drum by the action of the pressurized fluid on pistons. The friction created by this contact effectively transforms the kinetic energy of the vehicle into thermal energy. Any size or weight of the vehicle can be safely and controllably decelerated with the help of this dependable and consistent process. The pressure decreases when the brake pedal is released, enabling the brake parts to disengage smoothly. Pascal's law, therefore, serves as the foundation for hydraulic braking systems, ensuring their accuracy and efficiency in contemporary automobiles.

3.4. System Development

At first, Ultrasonic Sensor measures distance to the obstacle (such as a CD disk. The Esp32 processes the sensor data and triggers the relay when the distance is less than 20 cm then, relay activates the solenoid lock which is done when the relay gets triggered by Esp32 as ultrasonic sensor detects any obstacles. The Solenoid Lock locks or unlocks to actuate the hydraulic system & finally, syringe-Based Hydraulic System controls the force from the solenoid lock to the brake piston. The distance measured by ultrasonic sensor is sent to cloud and in case of relay triggering the brake status can be monitored live which is a hypothetical situation of vehicle and human safety.

3.4.1. Technical Process

Table 1. System Components

Components	Uses
Ultrasonic Sensor	Set up the sensor to measure distance.
Esp32	Program the Esp32 to read sensor data, process it, and control the relay & send data to ThingSpeak IoT platform.
Solenoid Lock	When the relay is activated, the solenoid lock releases, allowing the hydraulic system to activate.
Hydraulic System	Connect the solenoid lock to the syringe plunger to push the brake piston

The ultrasonic sensor is used here to measure the distance and then, the values of echo and trig pin are processed by Esp32 for calculating required distance value. The solenoid lock is actuated by relay if the distance is less than the threshold which we have supposed as 20cm for experimental analysis. The hydraulic system syringe piston is actuated by the solenoid lock.

we have,

$$Ultrasonic\ sensor\ distance\ =\ Distance\ =\ (Time\ \times\ Speed\ of\ Sound)\ /\ 2 \tag{1}$$

3.4.2. Hardware Design Overview

(i) Mechanical Design

- Ensure the syringe and pistons are appropriately sized for the brake force needed.
- Connect the syringe's plunger to the solenoid lock using a mechanical linkage.
- Design a setup where the movement of the brake piston is directed towards the CD disk.

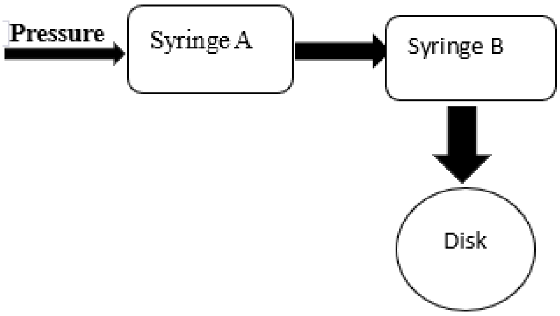

Figure 4. Hydraulic Braking Mechanical System

(ii) Electronic Design

- Program the Esp32 to read sensor data and control the relay & connect to IoT system.
- Connect the relay to the solenoid lock.
- Test the entire electronic setup to ensure proper communication and functioning.

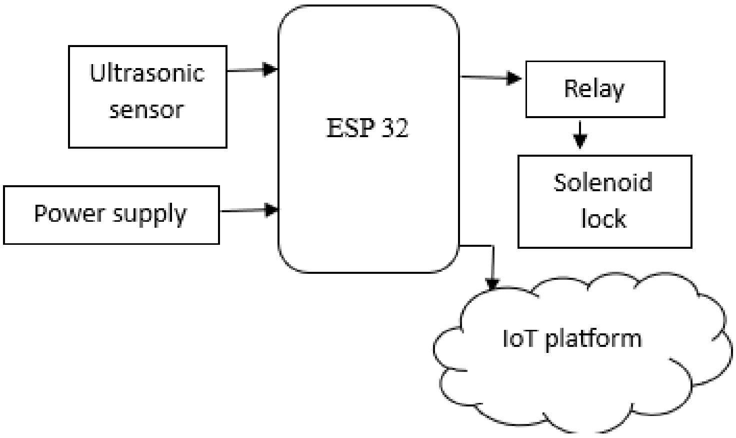

Figure 5. Block Diagram of the Electronic System

Esp 32, which receives sensor data as input, processes it for distance calculations, and then sends the impulse to the relay in accordance with the condition that is based on distance as stated before, is our system's primary brain. Data from the sensor-monitored distance and relay value are simultaneously delivered to the cloud with a 15 second delay.

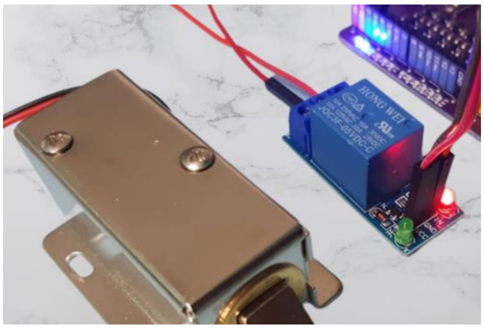

Figure 6. Arduino Based Relay Test

A relay triggering test is shown in figure 6, that actuates the relay to push and pull the piston tip in order to exert pressure on the corresponding syringe piston.

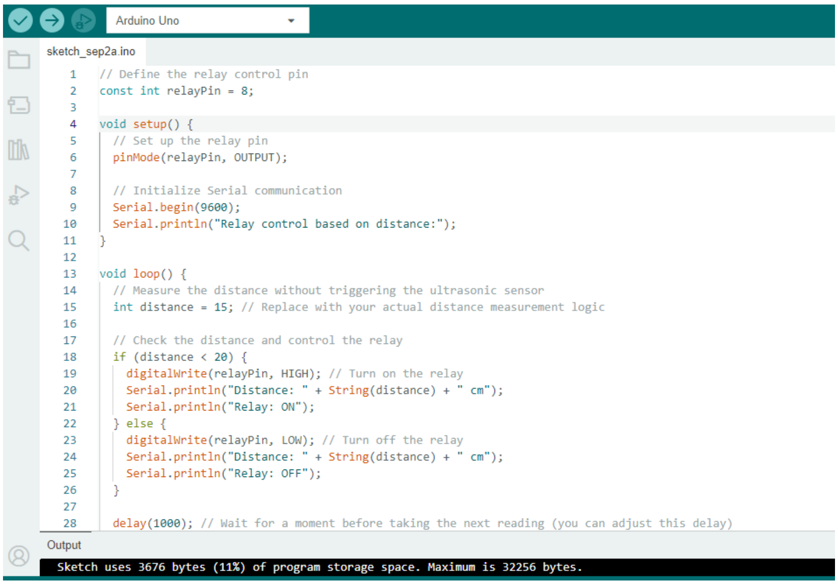

Figure 7. Arduino Sketch Code

By actuating the relay, we concurrently tested the solenoid lock and then looked for potential outcomes. The test was carried out in order to provide the piston a precise control so that it could drive the appropriate syringe and apply brakes to the disk, which is spun by a low-power DC motor.

4. Results and Discussion

Thus, the proposed method of detecting any impediment and applying brakes using a syringe piston on a disk was proved to be quite effective with the system. For suggestions on developing machines without accidents, it would be crucial to improve this electro-mechanical automated approach. Other hydraulic machinery can also benefit greatly from the technology. As seen in figure 3, the disk braking was largely satisfactory and worked as intended during system startup. brakes are used considerably more effectively. The cloud monitoring is effective to monitor the vehicle obstacle and its safe condition indicated by relay status. The research's outputs make excellent prospects for many applications.

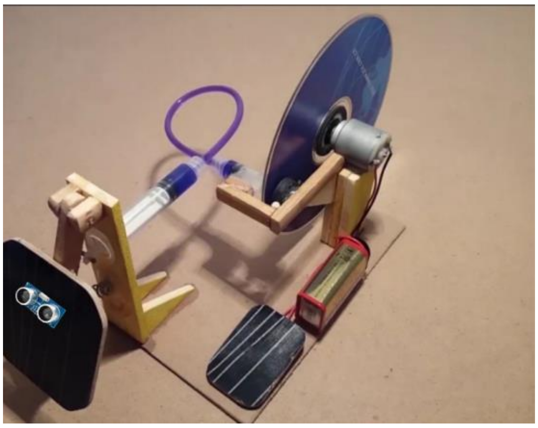

Figure 8. Final System Prototype

The solenoid lock tip is attached to the piston's top and coupled to the Esp32 board PCB mounted to the wooden surface housing. The ultrasonic sensor exerts hydraulic force, as shown in figure 8. The ultrasonic sensor functions as an eye, giving distance information to the Esp32 microcontroller, which processes it to meet the requirements shown on the flowchart.

Table 2. System Test Results

Iteration	Ultrasonic sensor distance in centimetres	Braking condition
i.	22cm	False
ii.	18cm	True
iii.	23cm	False
iv.	15cm	True
v.	14cm	True
vi.	19cm	True
vii.	20cm	True
viii.	25cm	False
ix.	24cm	False

As shown in the above table, when the distance recorded by the ultrasonic sensor is less than the threshold value of 20 cm, braking is applied because the vehicle has encountered a barrier. The converse is true when the distance is larger than the threshold value, which indicates that the vehicle is safe to drive. The true condition yields that brake must be applied and alternate in case of false condition.

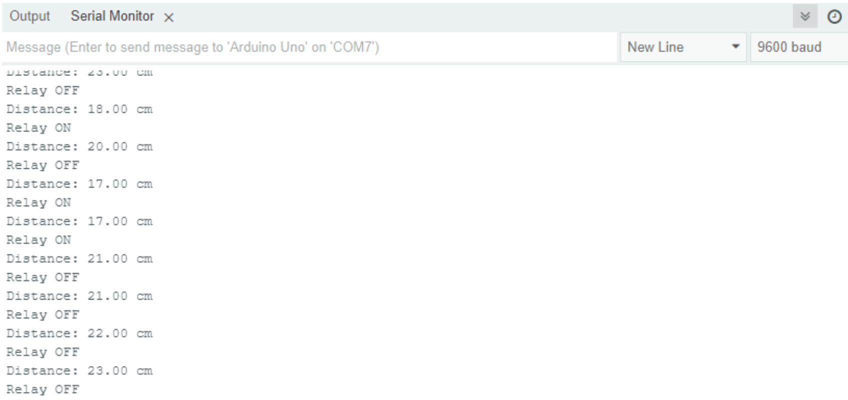

Figure 9. Serial Monitoring of Status of System

We see that distance causes relay to trigger and thus, brakes can be applied for the halt of the disk spinning procedure. The distance threshold is essential to locate a specific obstacle that causes blockage to the system.

4.1. IoT Result Analysis

Figure 10. IoT Monitoring of System

Esp 32, the primary processor of the system, which accepts sensor data as input and the integration of ThingSpeak and IoT in the proposed automatic hydraulic brake solution is essential for remote system monitoring and control. The microprocessor gathers this distance information as soon as the ultrasonic sensor detects an obstruction within its 20 cm range, and at the same time, it activates a relay linked to a solenoid lock, allowing the brake system to push the syringe's piston and apply the brakes. The microcontroller's capacity to connect to the internet—typically over Wi-Fi or Ethernet—and communicate with the IoT platform ThingSpeak is where the IoT component comes into play. ThingSpeak acts as a central location for the gathered information visualization and live monitoring.

The distance value in field 1 of the IoT chart represents live monitoring, and the relay status in field 2 of the chart, which is '0' for high and '1' for low, indicates the danger of an accident. This analysis aids in providing us with the various time instant values that the ultrasonic sensor is monitoring, and the related field status is the status of the system braking when the brake state indicator relay is triggered, as shown by the above signal. The lamp emits a dark red glow when it detects a threat or obstruction. Time is indicated on the X-axis, and the sensor-measured distance is shown on the Y-axis. When the sensor reads below 20cm distance of obstacle, it indicates danger; when it reads over the threshold, safe status is represented in another field.

This system can be used to construct a variety of real-world systems. For the creation of cutting-edge systems, this idea may be crucial.

4.2. System Applications

1) For low-speed applications, such as tiny carts or do-it-yourself projects, this method could be utilized as a straightforward emergency brake.

2) Similar technology for recognizing any necessary body using computer vision and making autonomous can be developed for other hydraulic cranes and various devices.

3) The method can be used to detect any obstructions in the path of small UAV bodies as well.

4) If the job is put into use in the real world, human load can be completely reduced.

4.3. Future Works

i. OpenCV application: Computer vision-based system development can be done to enhance the quality of the automation system.

ii. Enhanced system: Using a general robotic car body

iii. Raspberry-Pi powered: Developing a fully automatic robotic system that used hydraulic braking system with AI algorithms for precise control

iv. Improvement in Braking Force: Experimenting with different syringe sizes, hydraulic setups, and materials to enhance the braking force and efficiency.

v. Control Enhancements: Implementing more sophisticated control algorithms to improve braking response and accuracy.

vi. GPS system use: GPS tracking system usage for more accurate system position monitoring.

5. Conclusions

In conclusion, the syringe-based hydraulic brake system based on Pascal's law presents an ingenious solution for creating a cost-effective braking mechanism. By harnessing the principles of Pascal's law, which states that a change in pressure applied to an enclosed fluid is transmitted undiminished to all portions of the fluid, the system utilizes the force exerted by the solenoid-activated hydraulic setup. This force, facilitated by the syringe plunger, is effectively transmitted to the brake piston, enabling braking action on the CD disk. The use of IoT in this research is an addition to monitor a vehicle system progress and its safe and unsafe state for assurance of human safety.

While this research showcases the amalgamation of electronics, mechanics, and hydraulics, it also underscores the importance of Pascal's law in fluid transmission within confined systems. This study, which resonates with the fundamental principles of fluid mechanics, lays the groundwork for future efforts in inexpensive and inventive brake solutions, despite potential force and precision limits. When it comes to the development of autonomous systems, system development is extremely important. This IoT-powered solution may work well in practical situations. This is a fundamental idea in the realm of embedded systems and automation, while being extremely straightforward.

References

[1] Lacatan, Luisito L., Rico S. Santos, Joel W. Pinkihan, Roderick Y. Vicente, and Roger S. Tamargo. "Brake-Vision: A Machine Vision-Based Inference Approach of Vehicle

Braking Detection for Collision Warning Oriented System." In 2021 International Conference on Computational Intelligence and Knowledge Economy (ICCIKE), pp. 485-488. IEEE, 2021.

[2] Dalvi, Rohan E., Ramesh G. Sutar, Prashant H. Karke, and Jitendra B. Satpute. "Design and development of hand brake release system." *Global Res Dev J Eng* 2, no. 6 (2017): 280-284.

[3] Ram, Jvs, K. M. S. V. Manikanta, G. Pavanth, B. Jagadeep, and B. Raghu Kumar. "Automatic braking system using ultrasonic sensor." *International Journal of Innovative Science and Research Technology* 2, no. 4 (2017): 2456-2165.

[4] Navudu, Naveen, Aravind Ramapatruni, Jagadeesh Polaki, Jaya Surya Navagana, and Srihari Palli. "Automatic Breaking System Using Ultrasonic Sensor." (2021).

[5] Ajith Kumar, T., Arul Prakash, M., Ajith, R., Abishek, N., & Surendhar, S. (2019). Development of Ultrasonic Sensor Based Automatic Braking System. International Journal of Engineering Research in Computer Science and Engineering (IJERCSE), 6(7), 117.

[6] Cicchino, J. B. (2019). Real-world effects of rear automatic braking and other backing assistance systems. Journal of Safety Research, 68, 41-47. DOI: [DOI number].

[7] Duan, J., Li, R., Hou, L., Wang, W., Li, G., Li, S. E., Cheng, B., & Gao, H. (2017). Driver braking behaviour analysis to improve autonomous emergency braking systems in typical Chinese vehicle-bicycle conflicts. Accident Analysis & Prevention, 108, 74-82. DOI: [DOI number].

[8] Ohno, H., Suzuki, T., Aoki, K., Takahasi, A., & Sugimoto, G. (1994). Neural network control for automatic braking control system. Neural Networks, 7(8), 1303-1312.

[9] Isermann, R., Schorn, M., & Stählin, U. (2008). Anticollision system PRORETA with automatic braking and steering. Vehicle System Dynamics, 46(sup1), 683-694.

[10] Pérez, J., Saco, F., lanes, V. M. I., Jiménez, A., Diaz, J. C., & de Pedro, T. (2010). An RFID based Intelligent Vehicle speed controller using active traffic signals. SENSORS, 10(06), 15872-5888. DOI: 10.3390/s100605872.

[11] NE‟s. N. V., Houtenbos. M., & Hagen. I. S. C. (2008). Improving Speed behavior: The Potential of In-Car Speed Assistance and Speed Limit Credibility. IET Intelligent Transportation Systems, 2, 323-333.

[12] lanes, V. M. I., Onieva, E., Perez, J., De Pedro, T., & Gonzalez, C. (2009). Control of Velocidad Adaptativo para Entornos Urbanos Congestionados. Rev. Iberoam, automat. Informat. Ind., 66-73.

[13] Nayak, Sumant. Design and fabrication of electromechanical parking brake system. GRIN Verlag, 2014.

[14] Huang, C. T., et al. (2008). Design and testing of a new electric parking brake actuator. SAE International Journal of Passenger Cars-Mechanical Systems, 1, 1217-1222.

[15] Wang, B., et al. (2013). Slide mode control for integrated electric parking brake system. Mathematical Problems in Engineering.

[16] Liao, Y. S., Huang, C. T., Chen, C. T., Cheng, S. Y., Chen, B. R., & Huang, F. Y. (2010). Novel Design of the Integrated Electric Parking Brake System. SAE Technical Paper, 2010-01-1707.

[17] Pascal Law - Formula, Application & Derivation, retrieved from: Pascal Law - Formula, Application & Derivation (vedantu.com)

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