

Development of an Automatic Braking Mechanism Using Arduino, LiDAR, and Infrared Sensors to Improve Motorcycle Safety

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Article Information	ABSTRACT
Article History Received: November 17, 2025 Revised : December 08, 2025 Published: January 04, 2026 Keywords: <i>Automatic braking system;</i> <i>Arduino uno;</i> <i>LiDAR;</i> <i>Microcontroller;</i> <i>Servo motor.</i>	The high number of motorcycle accidents due to rider negligence confirms the need for an active safety system that is able to respond to emergency conditions, while research on auto-brakes is still limited, especially in terms of the detection distance of objects which are generally only active when there are objects within 9 meters according to sensor calibration and control logic as well as the application in low-speed vehicles at least 5 km/h. This research designed an Arduino Uno-based auto-brake system with LiDAR and infrared sensors to detect objects in front of the vehicle, with a braking mechanism running a servo motor that presses the main brake. The research methods include hardware design, sensor-actuator integration, fuzzy logic programming, and stationary testing using bike-based prototypes with variations in distance and speed. The results showed that the system was able to respond effectively at a distance of 700 cm with a maximum braking angle of 40°, maintaining stability in sudden conditions, thus confirming the effectiveness of fuzzy logic-based auto-brakes in improving rider safety while opening up the direction of further research for two-wheeled adaptive safety systems.

INTRODUCTION

The high rate of traffic accidents is closely linked to driver-related factors or human error, which remains a major cause of road crashes around the world (Khatami et al., 2023). This problem is especially critical for two-wheeled vehicles, where a lack of awareness about safe following distances and reduced focus while riding increase the chances of collisions (MR. SAGAR B. PORLEKAR, 2017). Previous studies also highlight that, besides human factors, vehicle safety technologies, especially braking systems, play a key role in preventing accidents (Reza et al., 2021). These systems help vehicles slow down or stop safely under different road conditions (Feriyanto et al., 2015).

To face this challenge, the development of safety systems has resulted in automatic braking technology or autobrake which aims to reduce the severity of accidents by activating the brakes without requiring input from the driver (Zain et al., 2016). Based on these advances, this study proposes the development of an autobrake mechanism for two-wheeled vehicles (Dean et al., 2021). Addressing this gap, this study introduces a more affordable and practical approach by designing an Arduino-based autobrake system, LiDAR sensors, and infrared to detect obstacles and selectively activate the brakes in emergency conditions with an adaptive control approach (Merkel, 2023). Motorcycle accidents are still much higher than four-wheeled vehicles, with

braking often failing to effectively reduce speed at close quarters and high speeds due to human error. Research on motorcycle-specific autobrake systems is still limited, while existing solutions such as combi brakes face complex design constraints and relatively high costs (Basri et al., 2024). The contribution of this research is the development of an autobrake system that integrates LiDAR–IR sensors and fuzzy logic on a simple motorcycle platform, a configuration rarely tested on two-wheeled vehicle systems. The proposed system offers a real step in lowering the number of accidents and improving rider safety, particularly in areas with the dominance of motorcycles in traffic and accident statistics.

This research aims to design an automatic braking system based on the Arduino Uno microcontroller as the main control that can detect the distance and speed of the vehicle through the intervention of its supporting components including Lidar and infrared sensors, then precisely regulate brake intensity with the integration of a servo motor on the front disc. In addition, fuzzy logic-based algorithms to process data and produce adaptive controls that can adjust braking levels according to conditions are also applied, creating a mechanism that is safe, effective, and relevant to rider safety.

RESEARCH METHODS

System Architecture and Instrumentation Design

The autobrake prototype was developed with a system that combines power regulation, sensing modules, computational processing, and actuation in a single workflow (Lee et al., 2017).

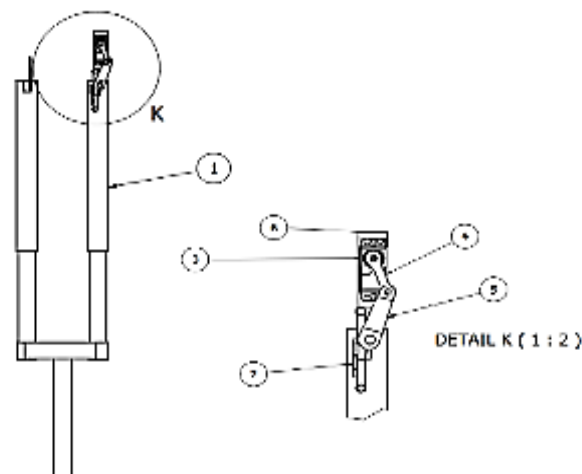


Figure 1. Auto brake Mechanism

The components listed in the picture are shown as follows: (1) Two-wheeled vehicle fork, (2) Disc Brake, (3) Servo, (4) Servo link, (5) Disc Brake link, and (6) Servo Bracket. The prototype of the autobrake braking system applied to two-wheeled vehicles is as a brake response designed so that the servo brake and its supporting components are integrated with the electronic system to be able to work automatically based on the input speed and distance provided so that emergency conditions can be resolved properly with the rules for applying fuzzy logic interference given to the servomotor.

A 12 V battery acts as the main power source. It connects through a main switch and an inline fuse for electrical protection and system reliability. The power is then split into two regulated lines using separate step-down converters (Sharma et al., 2018). The first converter lowers the voltage to 5 V for the arduino microcontroller, the sensing units, and the 20×4 LCD display. The second converter provides a steady 6.8 V output for the high-torque servo motor, ensuring reliable performance during braking .

The arduino uno acts as the main processing unit. It receives constant sensor feedback and generates control signals for the braking actuator (Ismailov, 2022). A Time-of-Flight (TOF) sensor measures distance with a maximum range of 12 m. This sensor connects through digital pins 10 and 11. A proximity sensor tracks wheel rotational speed, connected via pin 2 and isolated using a dual-channel optocoupler to reduce electrical noise. These two sensing modules give distance and speed inputs that the microcontroller processes to estimate the vehicle's closing speed and assess possible collision scenarios .

System feedback and operational parameters show up in real time on a 20×4 I2C LCD module. When the combined sensor inputs signal a hazardous condition, the arduino sends a pulse-width modulation (PWM) command through pin 5 to control the servo motor. This motor then moves the brake lever mechanically. The close interaction among the sensing layer, the computational unit, and the mechanical actuator creates a single autobrake control system that can perform emergency braking in real time (Stanly & Sutha, 2019).

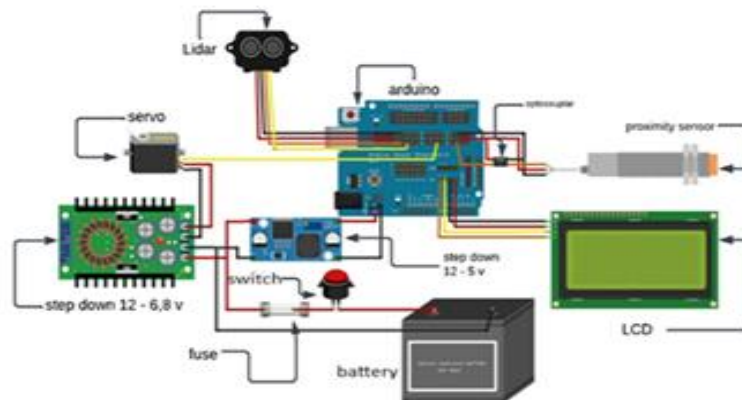


Figure 2. Wiring diagram design scheme

Experimental development method

This research takes an experimental development approach that blends electronic system design, mechanical construction, and control algorithm modeling to build an automatic braking system for two-wheel vehicles (Skrickij, 2020). The process begins by identifying issues related to accident risks, such as poor distance awareness and slow rider reactions during emergencies. A review of literature on microcontroller-based braking support, sensor fusion for obstacle detection, and smart control strategies provides the foundation for developing the device. Insights from previous studies help create a system that can carry out autonomous braking using real-time distance and speed feedback.

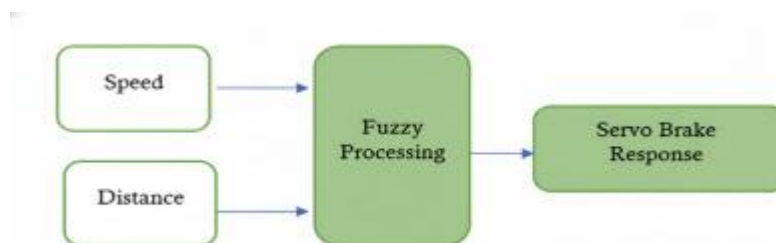


Figure 3. Scheme of integrated fuzzy processing method on autobrake system mechanism

The system design phase has two main stages: electronic integration and mechanical implementation. During the electronic integration stage, we select primary sensing technologies. This includes a LiDAR module to accurately measure forward distance and an infrared proximity sensor to gauge wheel rotational speed as a way to track vehicle motion. These sensors provide the necessary data for making braking decisions. We use the arduino uno platform as the central

processing unit because it is reliable, easy to program, and works well with other modules. A servo motor actuates the output by turning control signals into mechanical force on the braking system (Lu et al., 2016). We also include an OLED display to show operational parameters during testing. Additionally, a power management subsystem is organized to ensure stable electrical distribution and protect against voltage issues.

There are several sensors and actuators that are combined, including: LiDAR sensor, proximity sensor, and DS3240 servo. The specifications are shown in the following table.

Tabel 1. Decision Rules Based on Distance and Speed

Parameter	LiDAR	Proxynity Sensor	Actuator (Servo)
Type	TF Mini Plus	NPN Open Collector	Digital Servo
Operating voltage	5 V DC	5 – 12 V DC	6.0 – 6.8 V
Measurement Range	0.1 – 12 meter	-	-
Accuracy	± 5 cm (<6 m), $\pm 1\%$ (>6 m)	-	-
Detection distance	-	1 cm – 1,5 cm	-
Response time, detection angle	-	≤ 2 ms, $\pm 15^\circ$	-

The mechanical implementation stage focuses on designing a structural bracket to securely mount the sensors, actuator, and controller onto the vehicle prototype. This design ensures proper sensor alignment, reduces vibration, and keeps the brake mechanism working consistently. The mechanical layout is developed through repeated prototypes, followed by changes to achieve the best stability and ergonomic fit. While construction details are not shown as technical manuals, the focus remains on making sure that the mechanical structure supports reliable and precise system operation during testing.

Control algorithm development forms the foundation of the methodological approach. A fuzzy logic controller is created to process sensor inputs, specifically distance and speed, under uncertain and changing riding conditions (Aryadi et al., 2015). Membership functions for each variable are defined based on observed operational ranges (Fayaz et al., 2019). A rule base is constructed to reflect expert reasoning about safe braking responses. The Mamdani inference approach is chosen for its simple reasoning structure. The centroid technique is used for defuzzification. This produces a clear output that determines the braking intensity. The controller is programmed into the arduino platform to make real-time decisions. This enables the system to adjust braking force based on the severity of potential collision risk. The fuzzification process assigns a membership degree to each input based on its specific membership functions, which are generated automatically for every test value (Ali et al., 2015). The controller uses two input variables, distance and speed, and one output variable, brake effort. Brake effort is represented as a PWM signal that ranges from 0 to 255. Each variable is modeled with multiple fuzzy sets, which are defined using triangular membership functions (Apiecionek, 2025). This shape is chosen for its computational efficiency, smooth transitions between language terms, and easy implementation on microcontroller platforms like the arduino. The distance variable has five fuzzy sets that represent different proximity levels. The speed variable includes four fuzzy sets that describe various vehicle motion states. The output variable is divided into seven fuzzy sets that correspond to increasing levels of braking intensity. The use of fuzzy logic helps the system manage uncertainty and variability in real-world conditions (Lima et al., 2025). It offers a decision-making framework that resembles human reasoning in situations where clear boundaries do not apply. With this structure, the controller can understand distance and speed values. It then translates these into a suitable braking response, gradually increasing or decreasing effort (Jain et al., 2020).

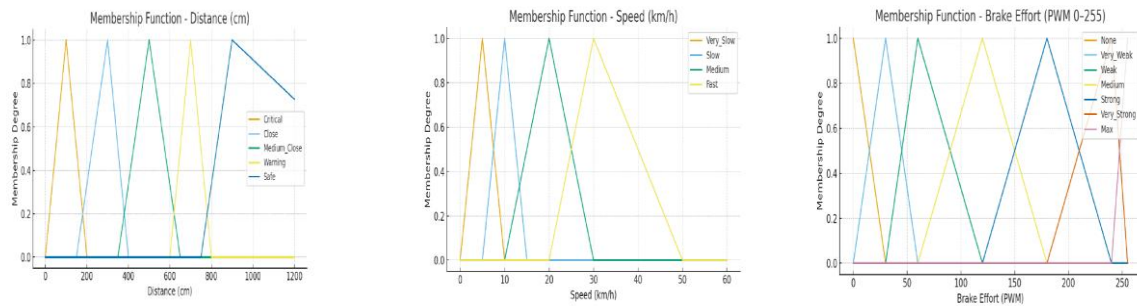


Figure 4. Membership function distance, speed and brake effort

Fuzzy inference systems are designed to capture the relationship between vehicle dynamics and braking needs. Twelve rules link distance to speed, resulting in adaptive braking response according to traffic conditions. The combination of distance categories and speed levels forms the braking intensity from very weak to maximum, so that the system reacts proportionally to the risk. These core rules are summarized in Table 2 as an overview of the decision-making process.

Table 2. Decision Rules Based on Distance and Speed

Rule Number	Distance Category	Speed Category	Braking Response
1	Critical	Any	Max
2	Close	Fast	Very Strong
3	Close	Medium	Strong
4	Close	Slow	Medium
5	Medium Close	Fast	Strong
6	Medium Close	Medium	Medium
7	Medium Close	Slow	Weak
8	Warning	Fast	Medium
9	Warning	Medium	Weak
10	Warning	Slow	Very Weak
11	Safe	Any	None
12	Safe	Vey Slow	Weak

One of those rules states that if the distance is very close, then the system will always react with the strongest force. In close quarters, it is speed that distinguishes the type of action that is carried out fast gets a very strong action response while medium, slow, and very slow get strong, medium, and weak actions respectively. For the med's closing distance, fast speed still requires strong action, medium speed provides a moderate response and slow drops it to weakness. In the alert zone, fast speeds are filled with moderate, moderate with weak, and slow responses with very weak actions. In short, if the distance is safe, the system does nothing no matter how fast the vehicle is.

The evaluation phase involves tests on a controlled track using a bicycle-based prototype that represents a two-wheel vehicle. Testing scenarios vary in terms of object distance, approach speed, and environmental conditions to check how well the system performs. Data is collected on how accurately it detects obstacles, the consistency of speed estimation, the time it takes to respond when braking, and how effectively it reduces speed before hitting the obstacle. Observations about system stability, rider interaction, and actuator responsiveness are noted as well. The collected data is then reviewed to assess the system's overall performance, pinpoint any limitations, and gauge the reliability of the fuzzy-based autobrake mechanism during emergency braking situations.

In stationer testing, the distance between the motorcycle and the object is set at a constant of 700 cm. The variable tested was the wheel speed, which was rotated with three variations namely 10 km/h, 25 km/h, and 32 km/h to simulate driving conditions. Each variation in speed

is repeated four times for distance to ensure consistency of results and data validation. So that there are 12 servo output data that are statistically analysed using DOE. Validation is carried out through statistical data distribution checks to ensure that the measurement results follow normal distributions, so that the level of confidence can be declared significant and reliable as the basis for evaluating the performance of fuzzy-based autobrake systems. Through these steps, the research aims to confirm whether intelligent sensing and adaptive control can be integrated into a small autobrake system designed for two-wheel vehicles. The detailed experimental analysis gives insight into the system's ability to improve rider safety by addressing human reaction delays and keeping safe stopping distances during unexpected events.

RESULTS AND DISCUSSION

Various previous studies have highlighted motorcycle braking systems, ranging from combi brakes that distribute brake force mechanically, to sensor-based systems and adaptive controls. Combi brakes improve stability but depend on the rider's reaction and have design and cost limitations. In general, autobrake technology is first developed and applied to four-wheeled vehicles before being adapted for motorcycles. The fuzzy logic-based approach emphasizes a more subtle and proportionate response to varied road conditions.

In this study, fuzzy logic-based autobrakes for motorcycles are positioned as a more adaptive and affordable solution. The system is able to adjust braking intensity according to distance and speed, with the advantages of simple design, low cost, and quick response without relying on the rider. Limitations are still related to sensor accuracy and field validation needs. Overall, the system offers a real step in improving safety and complements the existing literature with a focus on two-wheeled vehicles.

During the testing process, a single bicycle wheel served as the test object for evaluating the auto-brake system. The first step was to assemble all the electronic components for the test setup. Next, I opened the coding file to upload the program, which provided the data and instructions needed for the arduino.



Figure 5. Assembling the arduino box, electronic components, and the servo arm with the brake caliper arm.

Then the servo, infrared proximity sensor, and brake caliper were installed and assembled. Next, the servo arm was attached to the caliper lever to ensure it could push correctly. After that, the focus shifted to testing the proximity sensor to check if it was working properly and could detect objects in front of it. If everything is working well, the next step is to put together the entire circuit. Once the assembly is finished, the system and equipment are ready for testing.

In the testing phase, the process began at the shortest distance, which was 1 meter, ensuring that all components were still in a static state and the automatic braking had not yet been activated.



Figure 6. LCD display

As shown in Figure 4, the distance reading is 100 cm, the speed is 0 km/h, and the brake position is 0°.



Figure 7. Testing at a distance of 100 cm with a speed of 10, 25, 32 km/h

In Figure 5, the wheel rotation speed is 10 km/h, and the brake calliper lever angle is 40°. When the servo arm moves 40°, it reaches its maximum angle. At 100 cm, the system identifies this as a critical distance, which has been preset as very close, prompting the arduino to command maximum braking. The results shown in Figures 5 indicate that the program settings function correctly, as the servo applies maximum braking at the critical distance to stop the bicycle wheel.



Figure 8. Testing at a distance of 300 cm with a speed of 10, 25, 32 km/h

The test results at 300 cm show that when the critical distance is farther, the servo's push force on the brake calliper lever decreases. The resulting servo angles are 28° at 10 km/h, 31° at 25 km/h, and 33° at 32 km/h.



Figure 9. Testing at a distance of 500 cm with a speed of 10, 25, 32 km/h

The data obtained at 500 cm are: 18° at 10 km/h, 18° at 25 km/h, and 28° at 32 km/h.



The data obtained at 716 cm are: 10° at 10 km/h, 12° at 25 km/h, and 18° at 32 km/h.

Figure 10. Testing at a distance of 700 cm with a speed of 10, 25, 32 km/h

Based on the data shown on the LCD, a contour plot was made to show braking values in relation to velocity (km/h) and distance (cm). This visualization allows for a straightforward look at how braking force is distributed in different driving situations. It provides information on how the system reacts to changes in speed and distance.

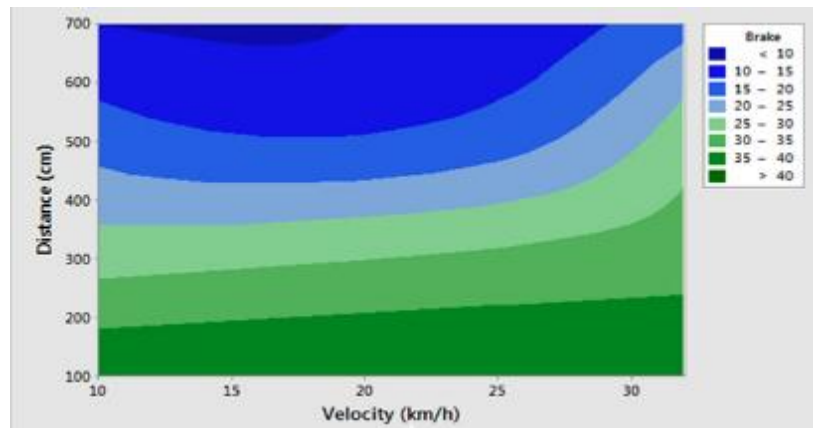


Figure 11. Contour plot of brake in degree

The braking response, influenced by changes in vehicle speed and proximity distance, can be described with the following equation. This formula shows how speed and distance interact to determine the braking force applied by the system. By modelling these relationships, the equation helps predict braking performance in different conditions and assists in designing and fine-tuning adaptive braking systems based on sensor input and control logic. $\text{Brake (degree)} = 38.99 + 0.2332 \times \text{Velocity (km/h)} - 0.04467 \times \text{Distance (cm)}$. The braking system shows a clear response based on the distance detected by the sensor and the vehicle's speed. As the gap between the vehicle and an obstacle gets smaller, the servo mechanism increases its force on the brake calliper, leading to stronger braking. On the other hand, when the distance is greater, the system lowers the braking intensity. This behaviour follows the rules of the predefined fuzzy logic control, which manages how braking force changes in real time. The system continually adjusts its output based on different combinations of speed and distance, ensuring quick and appropriate braking performance in changing driving conditions.

The braking system reacts to the distance measured by the sensor and the vehicle's current speed. When the sensor detects a closer obstacle, the system boosts the braking force by applying the brake calliper more forcefully through the servo mechanism. On the other hand, when the distance detected increases, the system lowers the braking force accordingly. This behaviour is guided by a set fuzzy logic control that adjusts the braking strength based on real-time data. The system reliably shows this pattern across different speeds and distances, ensuring that braking performance stays responsive, efficient, and meets safety standards in various driving conditions.

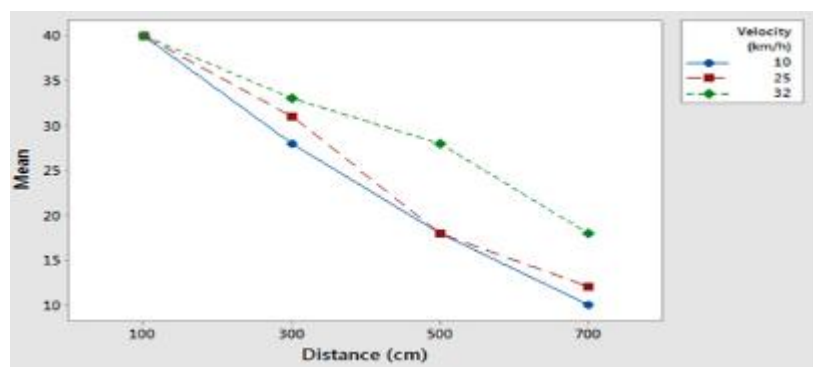


Figure 12. Interaction plot for brake data mean

The split-panel plot compares how braking performance changes with two important factors: vehicle speed and braking distance. The left panel shows that as speed increases; the average braking response also goes up. This means that higher speeds need more braking force to ensure safety and control. On the other hand, the right panel indicates that as the distance to an

obstacle decrease, the average braking response goes down. This suggests that when a vehicle gets closer to an obstacle, the system reduces braking intensity accordingly. These opposite patterns highlight how the braking system adjusts its output based on real-time sensor data and set control rules. The visualization illustrates how well the fuzzy-based auto-brake system responds to different driving situations.

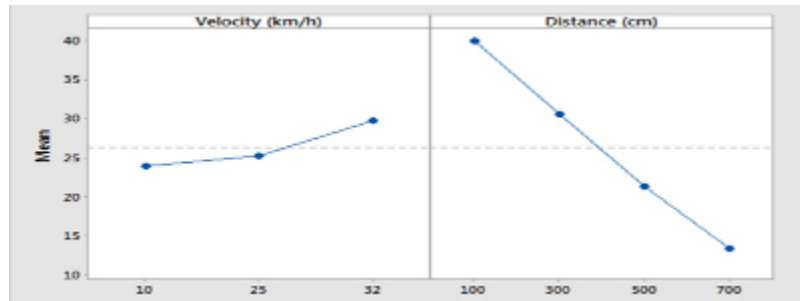


Figure 13. Main effects plot for brake data mean

CONCLUSION

The additional automatic braking system (Autobrake) for two-wheeled vehicles has been successfully designed and tested. The system has proven capable of responding to objects starting from a distance of 700 centimeters and successfully activating automatic braking (servo) while adaptively adjusting to the combination of distance and vehicle speed. This innovation is expected to significantly enhance riding safety by reducing human error in emergency situations.

Fuzzy-based autobrake systems have proven to be consistent and significant in stationary testing, with a distance detection accuracy of 97.7% against reference values. The 10 ms debounce mechanism ensures that the pulse is counted valid, while a maximum braking angle of 40° indicates the effectiveness of the system at a distance of 700 cm from the object. The fast response time confirms the potential of this system to support driving safety and is worthy of further development in dynamic conditions.

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