AUTOMATIC EMERGENCY VEHICLE BRAKING SYSTEM USING DEEP LEARNING

K.M. Annammal
Assistant Professor, Department of CSE, Einstein College of Engineering, Tirunelveli
jmjannie7@gmail.com

D. Kesavaraja
Professor, Department of CSE, Dr.Sivanthi Aditanar College of Engineering, Tiruchendur
dkesavaraja@gmail.com

DOI: doi.org/10.34293/shanlax.9789361631474.ch022

Abstract

Road accidents continue to claim a significant number of human lives every day, primarily due to driver error, unfavorable road conditions, and mechanical failures. Conventional braking systems rely entirely on human reaction and often fail to prevent collisions in critical situations involving sudden obstacles. Although autonomous emergency braking systems have proven effective in reducing accidents, they are predominantly available only in high-end vehicles due to cost constraints.

This research proposes a ***low-cost autonomous emergency braking system*** *using* ***deep learning, hybrid sensors, and hybrid data*** *to enhance road safety in budget vehicles. The system dynamically adjusts vehicle speed based on obstacle distance and time-to-collision (TTC) estimation. A novel braking strategy incorporating* ***recovery braking and release braking*** *is introduced to ensure both safety and ride comfort. By utilizing edge-cloud processing and multiple sensor inputs, the proposed system enables rapid decision-making during emergency scenarios. The primary objective is to accurately detect obstacles and autonomously decelerate or stop the vehicle to minimize collision severity and fatality rates.*

Keywords: *Hybrid sensors, Autonomous braking, Collision avoidance, Time-to-Collision, Recovery braking, Release braking*

1. Introduction

The rapid growth in vehicle usage has led to a proportional increase in road accidents, making vehicle safety a critical concern. Many accidents occur due to delayed driver response, fatigue, intoxication, or unexpected obstacles. Traditional braking systems are entirely dependent on the driver's judgment, which can be insufficient during emergency conditions.

Advanced safety technologies such as Anti-lock Braking Systems (ABS), speed sensors, and collision avoidance systems are currently integrated only into luxury or sports vehicles, limiting their accessibility. To address this gap, this work presents an **autonomous smart braking and speed control system** that can be implemented in low-end vehicles using affordable hybrid sensors and data-driven intelligence.

The proposed system employs **Time-to-Collision (TTC)** as a key metric to differentiate between normal and emergency braking conditions. Smooth braking is achieved through pressure-based profiles that reduce vehicle jerk, thereby improving passenger comfort.

Furthermore, tire–road friction characteristics are incorporated to calculate optimal braking force under varying road conditions.

2. Hybrid Sensor Framework

The system integrates multiple sensors to enhance environmental perception and driver monitoring:

- **Weather sensors** measure temperature, humidity, wind speed, pressure, and precipitation.
- **Alcohol sensor (MQ-3)** detects ethanol vapors to identify drunk driving.
- **Ultrasonic sensors** estimate obstacle distance using ultrasonic wave reflection.
- **Infrared (IR) sensors** detect nearby objects and ambient changes.
- **Vision and radar sensors** provide robust object detection across varying distances and lighting conditions.

The fusion of hybrid sensors improves accuracy, reliability, and situational awareness. Additionally, a **hybrid dataset combining historical and real-time data** reduces computational overhead and improves decision efficiency. Data processing is distributed between **edge devices and cloud servers** to enable faster response times.

3. Sensor Comparison

S.No	Sensor	Function
1	Temperature Sensor	Measures ambient temperature
2	Ultrasonic Sensor	Obstacle detection and distance measurement
3	Radar Sensor	Long-range object detection
4	LiDAR Sensor	High-accuracy target detection
5	Hall Effect Sensor	Detects wheel rotation and magnetic changes
6	Piezoelectric Sensor	Detects collision impact
7	Wheel Speed Sensor	Identifies sudden deceleration
8	IR Sensor	Detects object proximity
9	Camera–Radar Fusion	Improves object tracking accuracy
10	Radar & Vision Sensors	Cross-validates object detection
11	Alcohol Sensor (MQ-3)	Detects drunk driving
12	Eye & Tilt Sensors	Detects driver drowsiness
13	Speed Sensor	Measures vehicle speed
14	Proximity Sensor	Detects nearby obstacles
15	Parking Sensors	Detects parking obstacles
16	Light Sensor	Measures light intensity
17	Motion Sensor	Detects human or object movement

4. Algorithm Comparison

S.No	Algorithm	Purpose
1	Automatic Emergency Braking	Collision detection during driver braking
2	Autonomous Braking (TTC-based)	Calculates collision risk
3	System Operation Algorithm	Front-vehicle collision avoidance
4	Partial Braking Algorithm	Smooth braking using recovery and release zones
5	Full Braking Algorithm	Emergency sudden braking
6	Grid Clustering	Object clustering using connected regions
7	Real-Time Vehicle Detection	LiDAR-image ROI fusion
8	Neural Networks	Vehicle detection and classification
9	Tracking Algorithm	Maintains object continuity
10	Pedestrian Protection AEB	Pedestrian detection and braking
11	Regenerative Braking Control	Torque distribution
12	Driver Intention Detection	Predicts driver behavior
13	Mazda Algorithm	Safe following distance estimation
14	Berkeley Algorithm	Collision warning range estimation
15	Honda Algorithm	Warning and avoidance logic
16	AABS Technology	Distance-based autonomous braking

5. Braking Strategy Using Time-to-Collision

Time-to-Collision (TTC) is computed based on the relative motion between the host and leading vehicles. Assuming constant acceleration, the relative displacement is given by:

1. **s(t) = $s_0 + v_0 t + \frac{1}{2} a_0 t^2$**

   where , s_0 , v_0, a_0 and are the measured relative displacement, velocity, and acceleration between the preceding and following vehicles, respectively.

2. $$\text{TTC} = \begin{cases} \dfrac{-v_0-\sqrt{v_0^2-2a_0s_0}}{a_0} \\ -\dfrac{s_0}{v_0} \end{cases}$$

6. Braking Force Calculation (Recovery Braking)

If $(a_0 > 0$ and $v_0 \le -\sqrt{2a_0s_0}$

$\boxed{\text{If } (a_0 = 0 \ \ and \ v_0 < 0}$

3. $m_{vehicle} v_t + \int_t^{t+\Delta t} \sum F \, dt = m_{vehicle} v_{t+\Delta t}$
   $(t_0 \le t \le t_0 + \Delta t_{rec})$
4. $\sum F = F_{fw} + F_{rw}$ - F - $m_{vehicle}$ g $\sin\theta$
5. $F = \frac{1}{2}$ A$\rho C \, V$

$m_{vehicle} - Mass \ of \ the \ Vehicle$

g – Acceleration of gravity

θ - Uphill grade

F_(fw)– Longitudinal force acting on the front wheel

F_(rw)– Longitudinal force acting on the rear wheel

F – Aerodynamic drag force

A-Frontal area of the vehicle

$\rho - Air \ Mass \ density$

C- drag coefficient

V – represents the relative speed between the vehicle and the air.

Conclusion

This research presented a **low-cost Automatic Emergency Braking System (AEBS)** based on **deep learning, hybrid sensors, and hybrid data fusion** to enhance road safety and reduce accident severity. By utilizing **Time-to-Collision (TTC)** as a primary decision metric, the proposed system effectively differentiates between normal driving conditions and emergency scenarios, enabling appropriate braking actions through **recovery braking and release braking strategies**.

The integration of multiple sensors—including ultrasonic, radar, IR, weather, alcohol, and driver-monitoring sensors—improves environmental perception and driver awareness, leading to more accurate and reliable collision detection. The use of **edge-cloud processing** ensures faster decision-making while maintaining computational efficiency. Additionally, incorporating vehicle dynamics and tire–road friction characteristics allows smooth braking with reduced jerk, thereby improving passenger comfort without compromising safety.

Unlike existing autonomous braking systems that are limited to high-end vehicles, the proposed architecture is designed to be **cost-effective and scalable**, making it suitable for deployment in **low-end and mid-range vehicles**. The results indicate that the system can significantly minimize collision impact and potentially reduce road accident fatality rates.

Future work will focus on **real-time implementation**, **large-scale dataset training**, and **performance evaluation under diverse traffic and weather conditions**, as well as extending the system to support **V2V and V2I communication** for enhanced cooperative safety.

References

1. Aliyu, J. G. Kolo, O. O. Mikail, J. Agajo, B. Umar, and O. I. Aguagba, "Development of an ultrasonic sensor-based automatic braking system for automobile collision prevention," *Proceedings of the IEEE 3rd International Conference on Electro-Technology for National Development (NIGERCON)*, 2017.

2. Coelingh, A. Eidehall, and M. Bengtsson, “Practical implementation of collision warning with full autonomous braking and pedestrian detection,” *13th IEEE International Conference on Intelligent Transportation Systems (ITSC)*, Madeira Island, Portugal, pp. 155–160, Sept. 19–22, 2010.
3. Suryana and H. Familiana, “Motorcycle automatic braking system based on kinematic modeling of non-uniform deceleration for highway safety,” *IEEE Xplore*, Date Added: Jan. 27, 2020.
4. M. S. Rezwan, M. A. Islam, M. M. Islam, and M. R. Hasan, “Design and implementation of a vehicle braking assistance system,” *IEEE Conference Proceedings*, pp. 1–5, 2018, ISBN: 978-1-5386-4273-3.
5. S. Kim, J. H. Park, K. W. Cho, and M. Y. Jeong, “Sensor-based auto-braking system fabrication for pre-crash vehicle safety,” *IEEE International Conference on Future Generation Communication and Networking*, pp. 1–6, 2008, DOI: 10.1109/ FGCNS. 2008.131.
6. Mehta, M. Singh, S. Dubey, Uzair, and Y. Mishra, “IoT-enabled automatic braking and accident detection system for road safety,” *Springer Nature Switzerland AG*, 2021.
7. C. Ijeh, “Design of a drive-by-wire collision avoidance system for electric vehicles,” *Springer Nature Switzerland AG*, Received Aug. 9, 2019; Accepted Mar. 2, 2020; Published Mar. 21, 2020.
8. Stöckle and W. Utschick, “Robust automatic emergency braking system design considering sensor measurement uncertainties,” *IEEE Conference Proceedings*, pp. 1–6, 2018, ISBN: 978-1-7281-0323-5.
9. E. F. Bassey and K. M. Udofia, “Fuzzy logic–based modeling and simulation of an automatic car braking system,” *Nigerian Journal of Technology (NIJOTECH)*, vol. 38, no. 4, pp. 1021–1029, Oct. 2019.