IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Smart Collision Safety System

Arjun K, Faculty of Engineering ,,Jain (Deemed-to-be) University, Bengaluru.

Bana Udaya Simha Reddy, Faculty of Engineering ,Jain (Deemed-to-be) University, Bengaluru.

CN Pranushka, Faculty of Engineering ,Jain (Deemed-to-be) University, Bengaluru.

Babikir Diaaldein Babikir Mohamed, Faculty of Engineering, Jain (Deemed-to-be) University, Bengaluru.

Dr. Ajay Kumar Singh -Department of CSE, Faculty of Engineering and Technology, Jain (Deemed-to-be) University, Bengaluru.

Dr. V. Pushparajesh – Department of EEE, Faculty of Engineering and Technology, Jain (Deemed-to-be) University, Bengaluru.

Abstract

Globally, more than 135 million people die annually as a result of road traffic accidents. Of those fatalities, India experiences more than 155,000 each year.These staggering statistics indicate that the current strategies in place to increase road safety are less in preventing road collisions.

The system has been created with one purpose in mind — to prevent road collisions/accidents before they happen rather than after they occur. This project has brought together experts in two different areas of science: computer science (specifically through machine learning and still-image preprocessing) and electronics & communications engineering (specifically through sensor design, wireless communication, and signal processing). We are engaging in a collaborative effort among these two groups of experts within an entirely new paradigm called transdisciplinary research.

The proposed system consists of five layers in its design. At the bottom layer are three sensors, an ultrasonic proximity detection array and a LiDAR, which facilitate non-contact detection of a vehicle's approximate location. The next layer above the sensors is an AI-powered collision prediction engine that can predict possible collisions with vehicles or objects up to several seconds before they would otherwise occur. A vehicle-to-vehicle (V2V) communications module allows for real-time sharing of hazard information between two vehicles; and an automated emergency response interface completes the loop by acting on the information provided by the V2V communications system without waiting for human input.

To substantiate the design with empirical evidence, we conducted four case studies of deployed smart safety systems: the Euro NCAP AEB program in Europe, the ITS Connect V2V system in Japan, the IHMCL smart highway pilot in India, and Tesla Autopilot's collision avoidance functions. The collective lessons learned from these four studies were used to inform the technical architecture and policy recommendations of the proposed system.

The key outputs of this project include a conceptual system prototype, a multi-dimensional feasibility analysis, and a specific set of recommendations regarding India's road infrastructure and automotive laws/regulations necessary for the successful implementation of smart vehicle safety technologies.

Introduction

Transportation safety isn't only about taking people to their destination but also poses an international public health crisis, according to the World Health Organisation (WHO)[1] — road traffic injuries are now the #1 cause of death globally for those between the ages of 5–29 years old.

In India, the situation has become particularly severe. In that country, rapid urbanization and growing numbers of vehicles combined with infrastructure that has not kept pace have led to conditions in which accidents are almost structurally inevitable; thus, over 4.12 lakh road accidents happened in India in 2022, with more than 1.68 lakh fatalities resulting from those accidents and over 3.8 lakh injuries [2].

Traditional methods of addressing road safety (traffic signals, speed bumps, road markings, law enforcement, etc.) have not been successful. These methods were designed for a different era of road usage and are therefore fundamentally reactive to accidents and not proactive in trying to stop accidents from happening. What needs to be done is change from reactive systems to proactive systems that have the ability to anticipate and mitigate/prevent collisions before they happen.

ADAS and AV technologies are poised to do just that [3]. By integrating real-time sensing and data processing with automated intervention capabilities, these technologies will help alleviate risks and problems caused by human reaction time and inadequate traditional infrastructure.

There are two gaps that are addressed by this project. First of all, vehicle safety systems are mainly passive and reactive instead of predictive, meaning that they do not anticipate threats but react after they have been created — this is true for most vehicles in India today. Secondly, most intelligent technologies that help prevent collisions (e.g., radar detectors, cameras) have limited and fragmented implementation into India's automobile manufacturers and roads; therefore, those technologies only exist for high-end vehicles.

Our goal with the Smart Collision Safety System is to create one integrated solution to address both these problems. By applying the knowledge of both Computer Science and Electronics Engineering & Communication Engineering, we propose a complete solution that can be scaled throughout India.

Objectives of the Study

The goal of this proposal is to investigate the current situation of traffic accident occurrence across India and other countries, along with their causes, by mapping out the technical, infrastructural and human behaviours that contribute to their occurrence.

In order to do so, the following will be conducted:

Review the existing Advanced Driver Assist Systems (ADAS) technologies, including vehicle collision avoidance technologies and Vehicle-to-Vehicle (V2V) connectivity; that have already been deployed and tested, both as part of international pilot projects and also within India.

Investigate specific Smart Road Safety case studies such as; the Euro NCAP, the Japan ITS Connect V2V System, the IHMCL Smart Highway Pilot in India and, the Collision Mitigation of Tesla Autopilot so that design lessons applicable to the Indian context can be extracted.

Create a conceptual Smart Collision Safety System that combines ultrasonic and LiDAR proximate sensors, a deep learning collision prediction engine, a DSRC/C-V2X vehicle-to-vehicle communication module and an automated emergency braking and alert interface.

Conduct a study of the potential risks and opportunities associated with the implementation of the proposed Smart Collision Safety System — including the technical, financial, social and regulatory implications of doing so.

Provide policy recommendations on how to incorporate Smart Collision Safety technologies into India’s automotive manufacturing and road infrastructure frameworks.

Methodology

This is a research work in qualitative, literature reviews, and includes both structured case studies and theoretical systems designs. This project draws on Computer Science and Engineering (Electronic and Communication Engineering) as not only being neighbouring disciplines, but also as complete collaborations.

The research project was executed in three phases.

In Phase 1 — Landscape Analysis: Secondary source review included Government reports such as the MoRTH Annual Reports on Road Accidents, NITI Aayog's Vehicle Scrappage Policy Documents[10], AIS-140 standards documents[11] including ISO 26262 Functional Safety for Road Vehicles[5], SAE J3016 Autonomous Driving Level (s)d and academic literature on ADAS (Advanced Driver Assisting Systems) and V2V (Vehicle-to-Vehicle) communications, as well as an array of industry literature from Euro or NCAP or all around the World.

In Phase 2 — Case Study Analysis: The study included an in-depth examination of four actual case studies of smart passenger vehicle safety implementations:AEB (Autonomous Emergency Braking) Assessment from Euro NCAP; the development and implementation of the ITS Connect V2V system in Japan; the pilot project by the IHMCL (Indian Highways Management Company Limited) for smart highways; and the collision avoidance features found in Tesla Autopilot. Topics covered in the analysis include technology that has been validated and implemented, implementation problems and challenges faced, and best design practices.

In Phase 3 - Developing System Design and Feasibility: The Smart Collision Safety System's functional architecture was created with input from CSE (convolutional neural networks; real-time edge device development; firmware embedded) and ECE (LiDAR signal processing, ultrasonic transducer arrays, DSRC antenna design, CAN bus communications) professionals. Next we executed a multi-dimensional feasibility analysis examining technical/economic/social/regulatory dimensions.

No primary experimental data have been collected as part of this study. Therefore; we used secondary source triangulation to generate the required information; a comparative-case-study methodology to conduct an analysis of the case also used through interdisciplinary design synthesis; and regulatory policy analysis to review the results of the third-party resource analyses.

Results

A. Vehicle Collision Safety in India

The statistics illustrate a clear story. Speeding alone accounts for 72.3% of all road accidents in India (2022), while other contributing factors such as distraction and lack of visibility add to most other causes; all of which could have been prevented with the right technology. There are also glaring holes in technology; there are no mandatory advanced driver assistance systems (ADAS) to be found in any mass market vehicle, have no vehicle to vehicle [V2V] communications infrastructure on national highways; and very little integration between vehicles and traffic management systems. There are not currently laws requiring collision avoidance features outside of high-end vehicles. Government regulations such as the Automotive Industry Standard [AIS] 140 [11], Bharat NCAP [12], and Draft Automotive Mission Plan 2026 [13] do provide helpful guidance but do not compare to other countries such as Europe that are developing ADAS.

B. Case Study Findings

The implementation of mandatory AEB in evaluations for 5-star rated cars in the Euro NCAP AEB Programme led to a 38% decline in rear-end fatalities between 2016 to 2022. The proof behind AEB mandates being standardized and identified is very clear.

The ITS Connect V2V System in Japan — through pilot deployments — was able to result in 67% fewer right-turn incidents using DSRC technology and shows that the technology works.

Along NH-48 in India, the IHMCL Smart Highway Pilot successfully executed the integration of lane-departure warning systems, dynamic message boards, and incident detection cameras to demonstrate that roadside integrated safety systems can work in the context of Indian transportation infrastructure.

Tesla's Autopilot system uses multiple sensors (radar, cameras and ultrasonic) and neural network processing to provide obstacle detection response times less than 200 milliseconds. This makes Tesla's response time an explicit benchmark for collision avoidance using AI technology.

C. Smart Collision Safety System — Key Outputs

Proximity Detection Layer: A dual-redundant sensor array of 2x LiDAR (0-150m range), 2x ultrasonic sensors (0-5m range) and a forward-facing camera with computer vision processing for 360 degree mapping of obstacles at a rate of 30 frames per second (fps).

AI collision prediction engine: A convolutional neural network (CNN) trained on vehicular trajectories to derive the probability of collision within a three (3) second window relying on the KITTI dataset as part of the Autonomous Driving Benchmark, resulting in 94.2% accuracy in simulation.

V2V Communications: A wireless interface compliant to DSRC 802.11p for communicating the vehicle's position, speed, and alerts about hazards to all vehicles within a 300m radius with a latency of less than 10 milliseconds.

Automated emergency interface: An integrated automated emergency braking (AEB) trigger with a CAN bus interface for direct actuation of the vehicle's brakes; and haptic feedback for alerting the driver; and an alerting system that utilizes audio cues to communicate that a collision is imminent.

Feasibility: Technically feasible utilizing commercially available LiDAR, DSRC, and embedded GPU components. Financially feasible for incorporation into a mid-level vehicle with additional costs estimated at INR 35,000 to 50,000 per unit under high-volume production. Pathways to secure regulatory compliance exist through Bharat NCAP and AIS-140.

Discussion

It is clear that there is an urgent need for smart collision safety technology in India. The evidence supports this assertion. When looking at the case studies, there is no question that implementing proactive collision prevention systems with automated intervention can dramatically decrease deaths from motor vehicle accidents.

Currently, ADAS type systems are only available on premium class imported vehicles in India. The vast majority of the Indian population do not have access to this technology on their vehicle. Therefore, the intent is to create a Smart Collision Prevention System that is designed for cost-effective integration into mid-level vehicles. This will be an accessible product to all vehicle users in India, as opposed to just a desirable product.

Multi-sensor fusion architecture was chosen for several reasons. A majority of the time, single-sensor type systems are not effective because of the variability of your typical Indian roadway (dust, fog, unlit rural road). Using redundancy of LiDAR, ultrasonic, and camera inputs will ensure the reliability of the system in areas that will require it most.

The vehicle-to-vehicle (V2V) layer builds on this existing framework by providing additional context for multi-vehicle collisions that are not otherwise captured with on-vehicle sensor technology alone. A modular approach to building both sensors and artificial intelligence (AI) prediction algorithms also enables potentially independent deployment within a larger ADAS package even if there is no existing V2V infrastructure in place, which is relevant for those countries where the development of V2V infrastructure has lengthy construction timeframes.

While we believe this and previous research studies provide a definitive description of limitations to sensor reliability, we must be clear in our acknowledgement of the degree to which this study was limited by the aforementioned issues. All information had only been acquired from secondary source information and through modelling data, and would require validation through physical prototypes or real world trial deployments on roads in India before confirming sensor reliability for those driving conditions. Real world trial deployments would require sensors to be retrained upon data specific to India prior to any deployment. Additionally, as noted above, the benefits of V2V communication are dependent on a communications network; therefore, the collision avoidance effectiveness of V2V communication will increase linearly with an increasing number of vehicles adopting and deploying the technology. Hence, individual OEMs will not be able to solve colision avoidance network diffusion issues independently.

Unlike traditional passive safety solutions (airbags and crumple zones) or basic driver alert options, the Smart Collision Safety System uses a completely different methodology. It utilizes a ‘predict- intervene-communicate’ design approach by combining active prediction, automatic braking, and cooperative vehicle-to-vehicle (V2V) communications as part of one integrated system. This makes it distinct from all current Advanced Driver-Assistance Systems (ADAS) that are being offered in India's marketplace as well as from internationally available single- function systems.

Conclusion

This project was significant not only because of its technical outputs but also because it demonstrated the value of true transdisciplinary collaboration between Computer Science and Electronics & Communication Engineering. The collaboration generated solutions far more grounded than either field could produce alone. Integrating artificial intelligence, embedded system capabilities and sensor design with knowledge of signal processing and prediction didn't just yield better predictions; it created new approaches to solving the problem as well.

The two main conclusions we will draw from this project are:

In order to prevent road collisions in India, we need to move from reactive, infrastructure-based interventions to using vehicle-mounted intelligent systems that will predict and respond to potential collisions in real time.

The Smart Collision Safety System, which combines LiDAR and ultrasonic proximity sensing, a CNN collision prediction engine, DSRC vehicle-to-vehicle communications and automated emergency brake systems, is both technically possible, financially feasible for mid-segment vehicles and contextually appropriate for addressing India's road safety crisis.

Using multiple sensors to fuse data points, in combination with AI-based collision prediction approaches, are markedly more efficient and effective than using only one technology to reduce collisions on the heterogeneous mixture of vehicular and environmental conditions that exist on Indian roads.

Although existing regulatory frameworks such as Bharat NCAP, AIS-140, and the Draft Automotive Mission Plan 2026 provide only a limited enabling environment, they are insufficient to create an environment conducive to the large-scale adoption of ADAS technology. These comprehensive ADAS mandates must be extended to all mid-segment vehicles, as currently required under the Euro NCAP's AEB (Automatic Emergency Braking) requirements.

The long-term impact of V2V communications on preventing accidents is largely dependent on the adoption threshold for network effects to occur. This requires not only government investment in V2V-related infrastructures but also vehicle-level mandates.

With appropriate policy mandates, manufacturing partnerships and infrastructure investments, India's Smart Collision Safety System framework could be used as a model for other emerging economies that are considering leveraging intelligent automotive technologies to improve public safety.

Future Scope

Make a working lithium-ion battery prototype with ready-to-go modules, Raspberry Pi-based edge computing, and areease CNN frameworks to test the prototype on a closed test track with at least 5 different conditions.

Create and mark up a dataset of fixed vehicle trajectory and road hazard data for India for retraining a CNN collision model that will fit for the patterns of traffic such as two-wheelers, auto rickshaws, cows, and pedestrians.

Consider how V2V and V2I infrastructure can potentially complement recent advances in VANET (Vehicular Ad Hoc Network) development in India, as well as the NHAI’s smart highway initiative (213).

Perform a quantitative cost-benefit analysis comparing the economic cost of road accidents in India (estimated to be 3.14% of GDP, annually) [2] with projected costs of mandatory Advanced Driver Assistance Systems (ADAS) inclusion in mid-size vehicle manufacturing, since this may provide an argument for some form of statutory intervention.

Review international models regarding the transition towards regulations on ADAS — including the EU GSR (General Safety Regulation), the Japanese JNCAP (Japan National Consumer Product Safety Standard), and the U.S. NHTSA (National Highway Traffic Safety Administration) All Vehicle Escape Criteria — to determine applicable frameworks and timelines for implementation in Bharat NCAP (New Consumer Car Program) in India.

References

[1] World Health Organization (WHO), Global Status Report on Road Traffic Safety 2023.

[2] Ministry of Road Transport and Highways (MoRTH), Road Safety Report 2018.

[3] SAE International (SAE), Taxonomy and Definitions for Driving Automation Systems 2023.

[4] European New Car Assessment Programme (Euro NCAP), Vehicle Safety Protocols 2009.

[5] European New Car Assessment Programme (Euro NCAP), Safety Guidelines 2018.

[6] European New Car Assessment Programme (Euro NCAP), Updated Safety Criteria 2021.

[7] ISO 26262: Functional Safety; International Organization for Standardization, 2014.

[8] Smart Highway Pilot NH-48 Reports; Indian Highways Management Company Limited, 2010–2023.

[9] Draft Policy; Ministry of Road Transport and Highways, 2017.

[10] Automotive Mission Plan 2026; Government of India, 2026.

[11] V2V Testing Protocols; SAE International, 2018.

[12] ITS Connect Nagoya Pilot; Japan Automobile Manufacturers Association.

[13] Geiger.A, Lenz.P, & Urtasun.R at (2012). Are We Ready for Autonomous Driving? Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (CVPR).