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The Development of Artificial Intelligence Systems for Automobile Bumper Systems to Reduce Impact Energy Caused by Collisions and to Control the Percentage of Damage Caused by Passengers and Vehicles

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Abstract: Research mainly focuses on the development of sustainable automobile front bumper intelligence systems that absorb maximum impact energy and reduce the damage caused by collisions with less weight and high strength, to develop he has come across material selection, Design, simulation, experimental testing, and validation. We also have implemented an artificial intelligence system inside the bumper system that senses the coming optical such as object, speed, direction, and force coming in contact with the vehicle and gives an alert to the driver in the form of the horn so the driver controls the situation., A collision sensor is fixed in the outer body of the bumper system and is used to detect or "sense" the obstructions coming into contact with the vehicle, Further signal is transferred to the controller, and the Display or buzzer A simple flow chart is plotted with programming algorithm is an effective way of demonstrating the Machine Learning capabilities to be used in AI controlling the impacts energy.

Keywords: *Artificial intelligence systems, Automobile front bumper systems, controller, Design, Simulation.*

1. Introduction

In recent years, there has been a significant focus on developing sustainable automobile front bumper systems that can absorb maximum impact energy and reduce the damage caused by collisions. This has led to extensive research in material selection, design, simulation, experimental testing, and validation. In addition, the integration of artificial intelligence (AI) systems within bumper systems has opened up new possibilities for improving safety and control [1]. This article will explore the development of AI systems for automobile bumper systems, highlighting their role in reducing impact energy and controlling collisions. To achieve this, researchers and engineers have turned to different parameters, such as the following design; a study was conducted on an existing bumper model and highlighted critical failure points; considering all these downfall points, we generated a unique bumper with the use of CAD tools, and CAD parameters are set as per AIS-006. Also, the design is stable and generates less vibration. Different materials analysis was conducted to calculate the best suitable material that has the quality of high strength with less weight, and some additives were added to it to increase the strength, which acts as the composite material in the bumper system. A quality check-up was conducted in the Hyper Mesh Tool, and further crash analysis was carried out on LS. Dyna solver and validated all the data with experimental testing [2]. An artificial intelligence system is added to enhance the performance and functionality of automobile front bumpers. This system works on the sensor, which senses and detects objects coming into contact with the bumper system and gives the driver an alert. The operation is based on flow chant, Programming language, and Controller. Figure 1 below shows the entire system introduction.

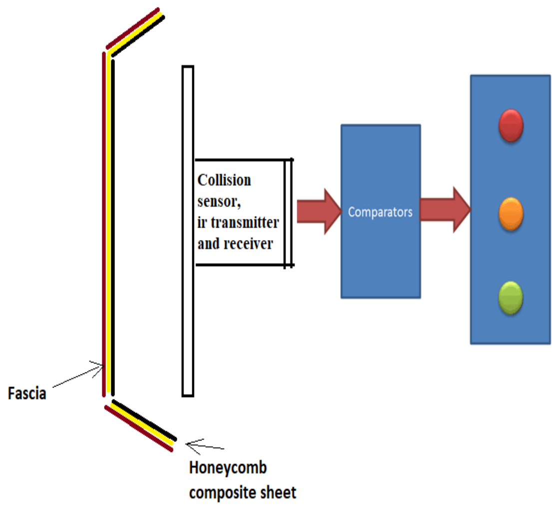

Fig.1. Base diagram for artificial intelligence bumper systems

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2. Materials and Methods

2.1. Material Selection for Bumper Systems

The selection of materials for automobile bumper systems is crucial in ensuring their effectiveness in absorbing impact energy. Traditionally, bumper systems were made of steel, which provided high strength but added significant weight to the vehicle. However, advancements in material science have led to the use of lightweight and high-strength materials such as composites, polyurethanes, polyamides, and blends of these materials with glass fibers [3, 4]. These materials offer a balance between strength and weight, making them ideal for bumper systems. In order to determine the most suitable material for bumper systems, various analyses such as static analysis, impact or crash analysis, dynamic analysis, and modal analysis are conducted. These analyses help evaluate the performance of different materials and identify the material that can provide the best weight-to-strength ratio. By considering factors such as stiffness, strength, durability, and cost, researchers can make informed decisions regarding the material selection for bumper systems. Steel, magnesium, aluminium, Glass fiber, Polyetherimide, and ABS Plastic are different metals whose requirements are allocated to the bumper, which are compared in Table 1 below. For the purpose of examining how the elastic modulus affects the impact behavior of bumpers, mechanical parameters of isotropic and metallic materials [5].

Table 1. Material properties of the models

Material	***Modulus of elasticity E (GPa)***	***Poisson's ratio μ***	***Yield strength Sy (MPa)***	***Density ρ (kg/m³)***
Commercial Steel bare 0-CS	207	0.3	190	7680
Aluminum 3105-H18	68.9	0.33	193	2720
Magnesium AZ31B	450	0.36	180	1740
S2 Glass	86.9	0.23	310	2460
Glass fiber	72	0.22	206	2540
ABS Plastic	2.5	0.37	48	1050
Polyetherimide	3.3	0.3853	105	1270
PEP	1.2	0.4	27	900

2.2. Design and Simulation of Bumper Systems

The design of bumper systems plays a crucial role in their ability to absorb impact energy and reduce damage. Advanced 3D modeling software, such as Catia, is used to create detailed models of bumper systems, allowing for accurate simulations and analysis. Impact analysis is performed on these models to assess their performance under different speeds and conditions.Through simulation, engineers can evaluate the stress, displacement, and strain values of different bumper materials. This information helps in comparing the performance of various materials, such as ABS plastic, polyetherimide, S2 glass, steel, aluminum, and glass fiber composites. By analyzing the results, it becomes evident that certain materials, such as S2 glass, exhibit lower stress values and better deformation characteristics, making them favorable choices for bumper systems [6, 7].

A finite element analysis is performed using LS-Dyna tool processor and Post-Processor and pre-processor we have used hyper mesh tool where an infinite degree freedom system is converted into finite by discretization method, and good quality mesh is generated which has a Jacobian ratio between 1 and 10 and also got better results in aspect ratio, Non-orthogonality, Volume ratio, Skewness, Tri max-min angle, Favor a 2D meshing or shell because the third aspect (consistency) of the relative plurality of corridors is not relevant if it varies according to the other two aspects (length and extent). The frame size is selected according to criteria of convergence criteria.

Table 2 below shows the parameters of meshing considered for the steel material, meshing parameters will change as the materials change, the CAD file is extracted in the pre-processor tool, and model clean-up takes place, meshing is done at the midplane of the geometry for smaller thickness and for larger thickness the meshing is done on the surface and it is extracted to the end of the surface [8, 9].

Table 2. Mesh information and Mesh information – Details

Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points for High quality mesh	16 Points
Element Size	45.5877 mm
Tolerance	2.27939 mm
Mesh Quality	High
Total Nodes	29620
Total Elements	15963
Maximum Aspect Ratio	30.91
% of elements with Aspect Ratio < 3	82
Percentage of elements with Aspect Ratio > 10	0.589
Percentage of distorted elements	0
Time to complete mesh (hh;mm;ss):	00:00:08

The disquisition results gave the compelled conditions, mass of the vehicle which is around 887 kg, and speed of impact which is 2km/ h to 6km/h. bolt confederations are given by transmits and legit pretensions are applied. The constrained model appears as shown in Figure 2

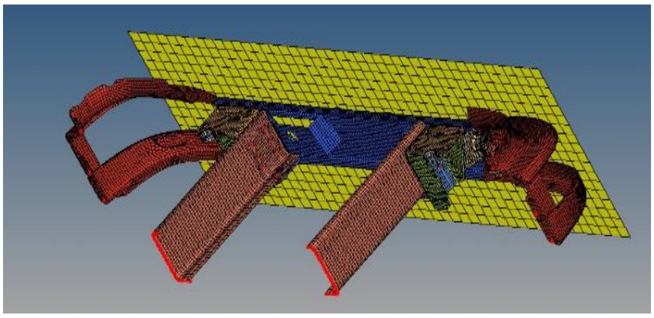

Fig. 2. After Pre-Handling model of Guard get together framework

The impactor receives the speed via the appropriate connections characterized between the guard and the impactor. The mass of the vehicle then's considered during influence conditions. Table 3 beneath shows the near-disquisition results [10-12].

Table 3. Shows the comparison of different materials for analysis of better material

Parameters	***Model Outcomes for Auto Front Guards***					
	ABS Plastic	***Polyetherimide***	***S2 Glass***	***Glass fiber***	***Steel***	***Aluminum***
Absolute Disfigurement	0.31992	0.31789	0.26661	6.2398	0.74322	*1.23211*
Stress	1.38e+09	1.85e+09	1.16e+10	8.57e+10	879083.88	*877002.44*
Strain	1.5741	1.505	0.16533	1.8058	0.000002	*0.000001*
Directional Twisting	0.031562	0.03471	0.043199	3.8416	0.008463	*0.004719*
Complete Speed	*2164*	*1475*	*1482.4*	*5696.6*	*2673*	*2503*

The density of fiber, S2 glass, polyetherimide, and plastic is lower than that of steel, as shown by a comparison of Tables 1 and 3. According to the findings of the impact study, which include stress, displacement, and strain values, S2 glass is a superior material. S2 glass is typically mixed with honeycomb composite material, which is recommended.

3. Results and Discussion

3.1. Experimental Testing and Validation

Before implementing bumper systems in actual vehicles, it is essential to conduct physical crash tests to validate their performance. Universal Test Vehicles (UTVs) are used as test rigs to verify the performance of candidate bumpers. These tests involve subjecting the bumper systems to various impact scenarios, including frontal and side vehicle impacts. During these tests, the bumper systems are evaluated based on their ability to protect the hood, trunk, grill, headlights, gasoline, exhaust, cooling system, and associated equipment. The performance criteria include the absorption of impact energy, deflection, impact force, stress distribution, and energy absorption behavior. By subjecting the bumper systems to rigorous testing, engineers can ensure their compliance with safety standards and regulations [13-15].

Experimental setup as shown in the figure below a low-speed impact test is performed with the help of an impact pendulum striker the installation procedure for the test, the Testing ground should be large enough to accommodate the impactor (striker) propulsion system and to permit after-impact displacement of the vehicle impacted and installation of the test equipment, the vehicle shall be at rest. Figure 3 below shows the experimental setup actually performing experimental testing.

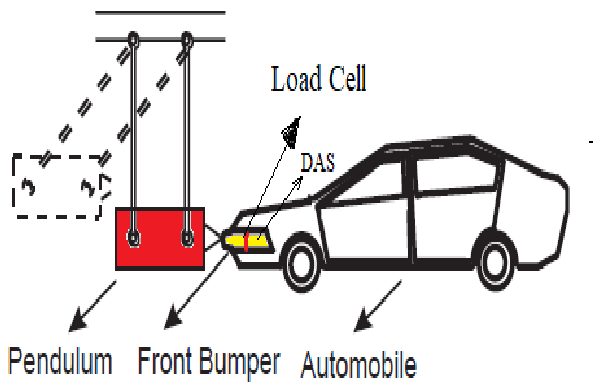

Fig. 3. Automobile front bumper system experimental testing setup

The impact pendulum hit the front bumper with the speed of 4 km/hr. at the center of the bumper and for the side 2.5 km/hr. Figure 4 below shows the experimental setup with velocity variation for the bumper system. The impact analysis followed as the front bumper of the vehicle where the impact hit a load cell is mounted and it can measure compressive loads up to 30.000 lb. The load button's mV/V output signal is amplified and conditioned by a signal conditioner, a USB225 Pro Elite high sampling rate USB signal conditioner, which is attached to the load cell output to guarantee precise alignment. With the data capture system, integration is being done here. Analyzing and Gathering Data to record the measurements of the impact force, start the data gathering system. As impact occurrences occur, gather data while accurately measuring the force levels. Determine the peak forces and assess the impact's effectiveness by doing a SENSIT analysis of the data [16].

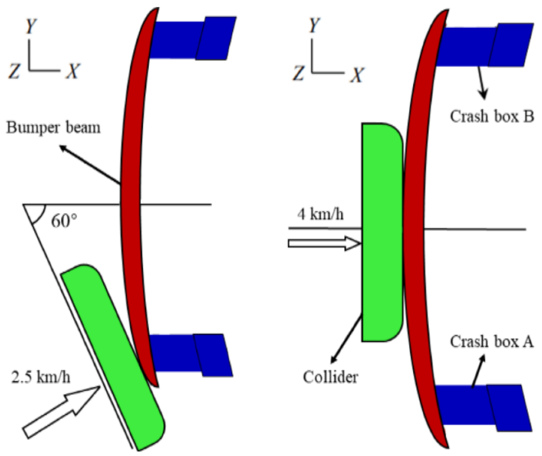

Fig. 4. Bumper system setup for speed variable

Experimental testing is performed with the help of a Pendulum striker to the car bumper and a load cell (LLB500), DAS calculates energy absorbed as 0.10707 kJ with an impact velocity (V) of 5.2km/hr. with 100 kg mass of anvil striking the bumper, Further, one more test is performed with the actual vehicle hitting the rigidly fixed wall the implementing AI system in the bumper for calculating the impact force Figure 5 shows an artificial intelligence bumper testing setup implant in the bumper system of the automobile [17, 18].

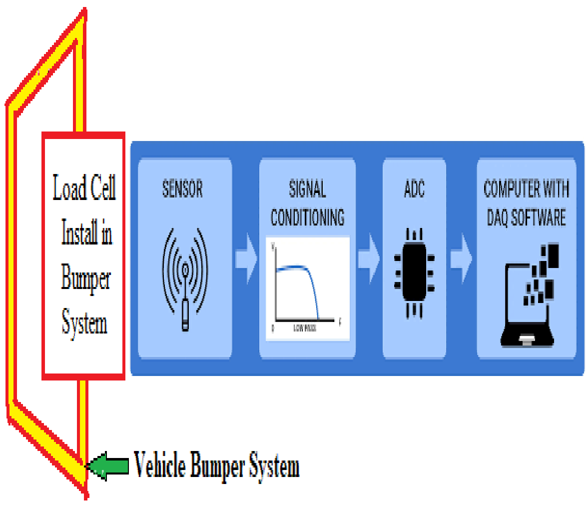

Fig. 5. Artificial intelligence bumper experimental testing setup

Actual crash test results with varying speeds for the front and side panels of the artificial intelligence bumper sensing system are shown below in Table 4.

Table 4. Artificial intelligence crash testing data with varying speed.

Load sensing sensor	*Signal Conditioner*	*Impact Velocity*	*DAQ Energy Absorb Analysis Outcome*	*Average force (F_a)*	*Maximum force (F_{max})*
LLB500	USB225 Pro Elite	4 km/hr. for the front panel of the bumper	617 J	12346 N	24691 N
		2.5 km/hr. for the side panel of the bumper	241 J	4823 N	9645 N

3.2. Integration of Artificial Intelligence Systems

The integration of artificial intelligence systems within automobile bumper systems has revolutionized their functionality and control. AI systems can sense and analyze the surroundings, enabling the bumper system to react and respond to potential collisions in real time. This improves the safety of both the vehicle occupants and pedestrians. One way AI systems are implemented is through the use of collision sensors. These sensors are fixed in the outer body of the bumper system and are designed to detect any obstructions coming into contact with the vehicle. When an obstruction is detected, a signal is transmitted to the controller, which processes the data and triggers the appropriate response. To alert the driver about potential collisions, the AI system can activate the horn as a warning signal. By integrating the horn control within the bumper system, the driver is immediately notified of any potential dangers. This allows the driver to take necessary actions to avoid or mitigate the impact [19-21].

Figure 6 below shows details of the artificial intelligence bumper system, A Collision sensor and infrared sensor are implanted on the front bumper, and the IR transmitter continuously emits the IR light and the IR receiver keeps on checking for the reflected light. If the light gets reflected back by hitting any object in front of it, the IR receiver receives this light. This way the object is detected, The collision sensor detects the path of a moving vehicle, further both this sensor calculates the actual distance, Motion, and Direction between the car body and the obstacle, and then prompts the driver to stop when any object comes in the contact of the system, through the controller, the IR and collision sensor at the front bumper controls the reflection and path of moving vehicle is reflected by obstacles, and the receiver receives the reflected signal and sends it to the amplifier circuit. The collision and IR calculate the propagation speed in the medium by using the time from the transmission of the IR and collision signal to the reception of the echo signal. The data is processed by the single-chip microcomputer, and then the distance, motion, and direction of the obstacle are displayed in the system and start the buzzer to remind the driver to operate in time. This process rum continue with artificial intelligence and learn itself with the help of machine learning to improve the process further. As per results of voltage values that were observed during the experiment the threshold range from 0.45-2.5 can be used for the detection and the reference voltage is 60 volts [22].

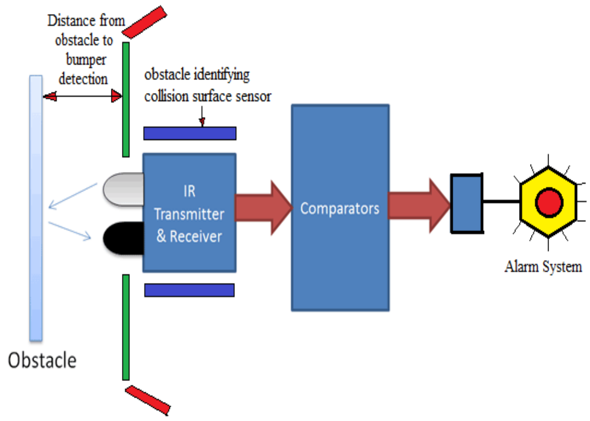

Fig. 6. Artificial intelligence collision alert system.

3.3. Machine Learning and AI Algorithms

Python language programming is developed for detecting vehicle collisions and obstacles. The system is implanted in a front bumper with an IR transmitter and receiver, collision sensor, controller, and data acquisition system, and this system gives an alert to the driver, and also Machine learning algorithms play a crucial role in the development of AI systems for bumper systems. These algorithms enable the system to learn from data and improve its performance over time. By analyzing patterns and trends, the AI system can make accurate predictions and decisions. A simple flowchart with a programmed algorithm is an effective way to demonstrate the machine-learning capabilities of AI-controlled bumper systems. The flowchart outlines the steps involved in sensing, analyzing, and responding to potential collisions. By continuously updating its knowledge base, the AI system can adapt to different driving conditions and improve its collision detection and response capabilities. Figure 7 shows a flow chart highlighting the Working of the AI bumper system [23].

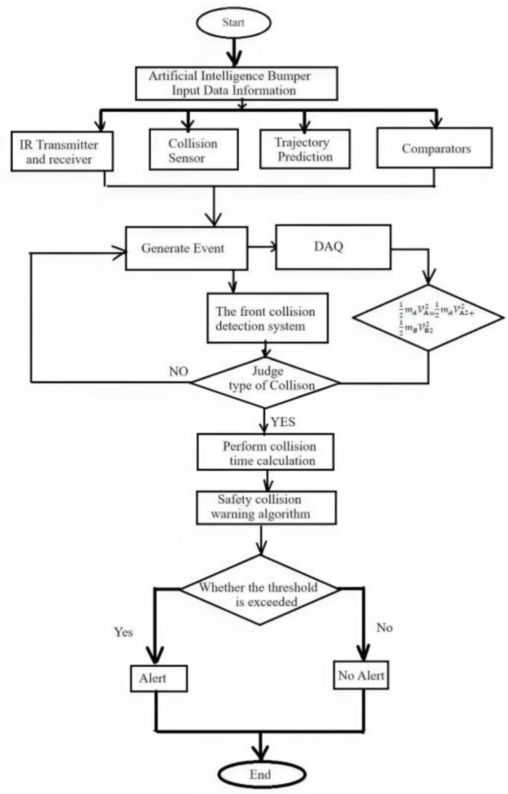

Fig. 7. Working principle of the AI bumper system flow chart.

Creating a complete vehicle collision and obstacle detection system with an IR transmitter and receiver, collision sensor, controller, data acquisition system, and driver alert is a complex project that involves both hardware and software components. Here, I'll provide you with a simplified Python script for the software part of the project that simulates the collision detection and alert system. Keep in mind that the hardware setup and integration are crucial and may require additional expertise. The actual sensor data is considered for output, Table 5 below shows program developed for identifying obstacles and objects coming in the contact of AI Bumper system and Table 6 algorithm output of Collision detection and indication to the driver.

Table 5. Algorithm for AI-Bumper system for checking collision function

```
import time

# Function to check for collision and obstacles
def check_collision():
# Simulate collision sensor data (replace with actual sensor input)
collision_sensor_data = input("Enter collision sensor data (0 for no collision, 1 for collision): ")

# Simulate IR transmitter and receiver data (replace with actual sensor input)
ir_receiver_data = input("Enter IR receiver data
```

```
(0 for no obstacles, 1 for obstacles): ")

return int(collision_sensor_data), int(ir_receiver_data)

# Function to send alert to the driver
def send_alert(alert_type):
if alert_type == "collision":
print("Warning: Collision detected! Please stop the vehicle.")
elif alert_type == "obstacle":
print("Warning: Obstacle detected in front. Slow down and maintain caution.")
else:
print("No alerts.")

# Main loop
while True:
# Check for collision and obstacle data
collision_data, obstacle_data = check_collision()

# Check for collision
if collision_data == 1:
send_alert("collision")

# Check for obstacles
if obstacle_data == 1:
send_alert("obstacle")

# Delay for a short period (you can adjust this depending on your requirements)
time.sleep(1)
```

Table 6. Parameters for detection of objects, obstacles and alert to stop the vehicle

1. *Enter collision sensor data (0 for no collision, 1 for collision): 1*
2. *Enter IR receiver data (0 for no obstacles, 1 for obstacles): 2*
Warning: Collision detected! Please stop the vehicle.

The following points below describe the algorithm of the AI and MI for the bumper collision system

1. The script has two functions: check collision to simulate sensor data and send an alert to send alerts to the driver.
2. Inside the main loop, we repeatedly check for collision and obstacle data.
3. We simulate sensor data using user input. Replace the input statements with actual sensor readings from your hardware.
4. If a collision is detected, it sends a collision alert. If an obstacle is detected, it sends an obstacle alert. You can customize the alert messages and actions as needed [24].

As per the calculation of the programming language and test carried out, the analysis results are shown in Table 7 below, we come across the data of the vehicle, and work accurately gives the results within 0.24 m/s if the object comes In contact with the sensor.

Table 7. Machine Learning Algorithms and test carried out analysis results.

Speed (m/s)	1	2	3	4
Acceleration (m/s)	0.18	0.24	.018	0.24
Collision status	false	false	false	True

The system integrates sensors, and a microcontroller (such as Arduino or Raspberry Pi), and sets up communication between the sensors and the software. The hardware setup and integration are critical for a reliable collision and obstacle detection system in a vehicle.

3.4. Benefits and Future Potential

The integration of AI systems within automobile bumper systems offers numerous benefits. These systems enhance safety by providing real-time collision detection and alerts to drivers. By reducing the impact energy and controlling the percentage of damage caused by collisions, AI-controlled bumper systems can significantly improve the overall safety of vehicles. Furthermore, the use of lightweight and high-strength materials in bumper systems allows for better fuel efficiency and reduced emissions. The improved design and functionality of bumper systems also contribute to the aesthetics and overall appeal of the vehicle [25, 26].

As technology continues to advance, the potential for AI-controlled bumper systems is vast. Further research and development in this field can lead to even more sophisticated systems that can autonomously react and respond to potential collisions. This can revolutionize the automotive industry, making vehicles safer and more efficient.

4. Conclusion

The development of artificial intelligence systems for automobile bumper systems has brought about significant advancements in safety and control. By integrating AI algorithms and machine learning capabilities, bumper systems can effectively reduce the impact energy and control collisions. The selection of suitable materials was done with simulation and experimental testing. Glass fiber is a better material combined with composite material, which is 70% stronger as compared to the other materials and has less weight. A honeycomb structure is suitable with the preferred material, and combined with advanced design and simulation techniques, it ensures the optimal performance of bumper systems. With further research and development, the future holds even more potential for AI-controlled bumper systems to enhance vehicle safety and efficiency. Additional Information: Research mainly focuses on the development of sustainable automobile front bumper intelligence systems that absorb maximum impact energy and reduce the damage caused by collisions with less weight and high strength. Material selection, design, simulation, experimental testing, and validation have been key areas of development. The integration of an artificial intelligence system inside the bumper system allows for the sensing of optical cues such as objects, speed, direction, and force coming into contact with the vehicle. This information is then used to alert the driver through the horn, enabling them to control the situation. The use of collision sensors and controllers further enhances the capabilities of AI-controlled bumper systems.

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Author contributions

Sagar Dhamone: Conceptualization, Methodology, Software, Field study, Data curation, Writing-Original draft preparation **Arumkumar Padmakumar:** Software, Validation. Field study, Visualization, Investigation, Writing-Reviewing and Editing.

Conflicts of interest

The authors declare no conflicts of interest.

Reference

[1] N. S. Muhammad, A. Hambali, J. Rosidah, W. S. Widodo, and M. N. Ahmad, "A Review of Energy Absorption of Automotive Bumper Beam," *International Journal of Applied Engineering Research*, vol. 12, no. 2, pp. 238-245, 2017.

[2] A. Bhuyan, and O. Ganilova, "Crush Can Behaviour as an Energy Absorber in a Frontal Impact," *Journal of Physics: Conference Series, University of Glasgow 382 012009,* pp. 28–31, 2012, DOI: 10.1088/1742-6596/382/1/012009.

[3] R. Seshagiri, P. Vadnala, and V. Prasad, "Design and Analysis of Automobile Bumper," *International Journal of Innovative Technology and Exploring Engineering*, vol. 9, no. 1, pp. 512-516, 2019, DOI: 10.35940/ijitee.G5615.119119.

[4] F. J. Dolsa, J. Molinaa, F. J. Camachob, J.Marín-Moralesc, A. M. Pérez-Zuriagab, and A. Garciab, "Design and development of driving simulator scenarios for road validation studies," *XII Conference on Transport Engineering Valencia Spain*, vol. 18, pp. 289 – 296, 2016, DOI: 10.1016/j.trpro.2016.12.038.

[5] G. A. Umadevi, and N. Ramesh, "Design and Analysis of an Automobile Bumper*," International Journal of Research*, vol. 2, no. 3, pp. 17-22, 2015.

[6] L, BRUCK, B. HAYCOCK, and A. EMADI, "A Review of Driving Simulation Technology and Applications," *IEEE Open Journal of Vehicular Technology,* vol 2, pp. 1-16, 2021, DOI: 10.1109/OJVT.2020.3036582.

[7] A. D. Katkar, and J. S. Bagi, "Bumper Design Enhancement through Crash Analysis," *International Journal of Engineering Technology, Management and Applied Sciences,* vol. 3, pp. 272-279. 2015.

[8] T. Kale, and G. Gulwade, "Study and Design of Front Bumper for Light Motor and Heavy Motor Vehicles," *International Research Journal of Engineering and Technology*, vol. 8, pp. 8-15, 2021.

[9] B. Du, Q. Li, C. Zheng, S. Wang, C. Gao, and L. Chen, "Application of Lightweight Structure in Automobile Bumper Beam: A Review," *Materials,* vol. 16, No.197, pp. 1-25, 2023, DOI: 10.3390/ ma16030967.

[10] H. Mohammadi, Z. Ahmad, S. A. Mazlan, M. A. F. Johari, G. Siebert, M. Petru, and S. S. R. Koloor, "Lightweight Glass Fiber-Reinforced Polymer Composite for Automotive Bumper Applications: A Review," *Polymers,* vol. 15, no. 193, pp. 1-30, 2022, DOI: 10.3390/polym15010193.

[11] H. Chang, Z. Su, S. Lu, and G. Zhang, G, "Application of Deep Learning Network in Bumper Warpage Quality Improvement," *Processe*, vol. 10, no. 1006, pp. 2-20, 2022, DOI: 10.3390/pr10051006.

[12] Y. Ma, Z. Wang, H. Yang, and Y. Yang, "Artificial Intelligence Applications in the Development of Autonomous vehicles: A Survey," *EEE/CAA Journal of automatica sinica*, vol. 7, no. 2, pp. 315-329, 2020, DOI: 10.1109/JAS.2020.1003021.

[13] S. Mertens, J. Krois, A. G. Cantu, L. T. Arsiwala, and F. Schwendicke, "Artificial intelligence for caries detection: Randomized trial," *Journal of Dentistry*, vol. 115, pp. 1-10, 2021, DOI: 10.1016/j.jdent.2021.103849.

[14] F. Schwendicke, J. C. Oro, A. G. Cantu, H. Meyer-Lueckel, A. Chaurasia, and J. Krois, "Artificial

Intelligence for Caries detection: Value of Data and Information," *Journal of Dental Research*, vol. 101, no. 11, pp. 1350-1356, 2022, DOI: 10.1177/00220345221113756.

[15] L. S. Iyer, "AI enabled applications towards intelligent transportation," *Transportation Engineering,* vol. 5, pp.1-11, 2021, DOI: 10.1016/j.treng.2021.100083.

[16] K. Kim, I. Jeong, and J. Cho, "Design and Implementation of a Video/Voice Process system for Recognizing Vehicle Parts Based on artificial Intelligence," *Sensors*, vol. 20, no. 24, pp. 1-28, 2020, DOI:10.3390/s20247339.

[17] S. Sathiskumar, G. R. Dhanush, and N. Dhavaneeswaran, "Automated Pneumatic Bumper For Vehicle Safety," *International journal of scientific & Technology research*, vol. 9, no. 2, pp. 224-229, 2020,

[18] G. D. Sharma, A. Yadav, and R. Chopra, "Artificial intelligence and effective governance: A review, critique and research agenda," *Sustainable Futures*, vol. 2, pp. 1-4, 2020, DOI: 10.1016/j.sftr.2019.100004.

[19] Y. Wu, L. Ma, X. Yuan, and Q. Li, "Human–machine hybrid intelligence for the generation of car frontal forms," *Advanced Engineering Informatics*, vol. 55, pp. 1-10, 2023, DOI: 10.1016/j.aei.2023.101906.

[20] B. B. Degu, W. Zhongmin, and Wenping, "Influence of Artificial Intelligence on Automotive Major in Vocational Education Training," *International Journal of Engineering Research & Technology*, vol. 12, no. 4, pp. 71-78, 2023.

[21] T. Y. Chai, and I. Nizam, "Impact of artificial intelligence in automotive industries transformation," *International Journal of Information System and Engineering*, vol. 9, no. 1, pp. 1-35, 2021, DOI: 10.24924/ijise/2021.04/v9.iss2/01.35.

[22] A. K. Tyagi, and S. U. Aswathy, Autonomous Intelligent Vehicles (AIV): Research statements, open issues, challenges and road for future," *International Journal of Intelligent Networks*, vol. 2, pp. 83-102, 2021, DOI: 10.1016/j.ijin.2021.07.002.

[23] A. M. Abdulghani, M. M. Abdulghani, W. L. Walters, and K. H. Abed, "AI Safety Approach for Minimizing Collisions in Autonomous Navigation," *Journal of artificial intelligence*, vol. 5, pp. 1-14, 2023, DOI: 10.32604/jai.2023.039786.

[24] S. M. Nam, J. Park, C. Sagong, Y. Lee, and H. Kim, "A Vehicle Crash Simulator Using Digital Twin Technology for Synthesizing Simulation and Graphical Models," *Vehicles*, vol. 5, pp. 1046–1059, 2023, DOI: 10.3390/vehicles5030057.

[25] D. Kumari, and S. Bhat, "Application of Artificial Intelligence Technology in Tesla-A Case Study," *International Journal of Applied Engineering and Management*, vol. 5, no. 2, pp. 205-218, 2021, DOI: 10.47992/IJAEML.2581.7000.0113.

[26] L. G. Keni, V. Singh, N. Singh, A. Thyagi, S. Kalburgi, and K. N. Chethan, "Conceptual design and analysis of a car bumper using finite element method," *Cogent Engineering*, vol. 8, pp. 1-10, 2021, DOI: 10.1080/23311916.2021.1976480.

[27] Moore, B., Clark, R., Muñoz, S., Rodríguez, D., & López, L. Automated Grading Systems in Engineering Education: A Machine Learning Approach. Kuwait Journal of Machine Learning, 1(2). Retrieved from http://kuwaitjournals.com/index.php/kjml/article/view/125

[28] Singh, S. ., Bharti, A. K. ., Pandey, H. ., Yadav, R. K. ., Sharma, D. ., & Shanker, N. (2023). Towards Automated and Optimized Security Orchestration in Cloud SLA. International Journal on Recent and Innovation Trends in Computing and Communication, 11(3), 215–222. https://doi.org/10.17762/ijritcc.v11i3.6339