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Non-contact Anti-collision Technology Based on Electromagnetic Repulsion and Levitation Theory

JunXi Chen*. Yuang Zhou and HuaYu Guo
School of Information Science and Engineering, Dalian Polytechnic University, Dalian116034, China
Email: 18710037383@163.com

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Abstract

With the development of the automotive industry and road conditions, cars have become essential for daily life and travel. However, the number of traffic accidents is rising rapidly, and rear - end collisions are common, posing a threat to safety. Anti - collision technology is crucial for road traffic, but existing ones can't reduce losses or prevent accidents. This paper focuses on non-contact anti-collision technology based on electromagnetic repulsion and levitation, using relevant conversion technology. Permanent magnet devices like electromagnetic coils are placed around the vehicle. When a collision is about to happen, the magnetic levitation mode is activated; when a collision occurs, emergency levitation braking is triggered to reduce losses and achieve levitation or repulsion. By analyzing previous collision problems, a vehicle-road cooperative collision avoidance method is proposed in combination with the active collision avoidance system. Simulation designs of rear - end collision, active collision avoidance, and magnetic levitation are completed using MATLAB.It's concluded that this technology has high future development value.

Keywords

Electromagnetic Repulsion; Electromagnetic Levitation; Non-contact Collision Avoidance; Dynamic Repulsion

1. Introduction

According to the national road traffic accident situation released by the Traffic Management Bureau of the Ministry of Public Security in 2024: A total of 238,351 road traffic accidents occurred, resulting in 67,759 deaths, 275,125 injuries, and direct property losses of 910 million yuan. There will be 24 major road traffic accidents with more than 10 deaths in 2024. The national mortality rate per 10,000 vehicles will be 3.6% in 2024, down 0.7% from the previous year. Although the casualty figures have declined compared to previous years, the casualty rate remains high, and combined with emerging driverless technology, traffic safety issues are of greater concern. A large amount of data shows that car crashes account

for a large proportion, among which rear-end collisions, though low in fatality rate and not given enough attention, have an extremely high probability of occurrence. In China, rear-end collisions on urban roads account for more than 30 percent, and even higher on highways. Although the single fatality rate is low, due to the frequent occurrence, the cumulative casualties and losses are astonishing, and it can also lead to traffic paralysis and secondary disasters. Therefore, exploring the mechanisms, influencing factors and preventive measures of rear-end collisions is of great significance for ensuring traffic safety and deserves attention from all sectors.

In terms of vehicle collision prevention, there are three technical modes: active, passive and assisted. Active systems such as the Forward Collision Warning (FCW) system can provide alerts to mitigate or prevent collisions; There are also automatic emergency braking (AEB), adaptive cruise control (ACC), etc. Passive devices include seat belts, body optimization, active headrests, etc. The assistance system assists the driver through the driver monitoring system (DMS), night vision and thermal imaging, and integrated electronic braking technology. However, various anti-collision technologies are mostly used for post-feedback adjustment and cannot autonomously remove obstacles.

This project mainly studies how to use the principle of mutual repulsion of magnetism and levitation technology more effectively to reduce the loss caused by collisions and thereby lower the accident rate. Compared with traditional anti-collision technologies that rely on monitoring feedback for avoidance, the magnetic levitation anti-collision system, which is dominated by magnetic force, can better address the possible negligence of drivers, effectively reduce the occurrence of rear-end collisions, and thereby safeguard the lives and property of traffic participants.

2. Research Content

This study focuses on a systematic study of magnetic levitation anti-collision systems' design, optimization, and validation. The main contents are as follows: First, explore the feasibility and mechanism of applying the magnetic force repulsion principle in automotive anti-collision, analyze the influence of magnetic field intensity and pole arrangement on anti-collision performance, and establish a mathematical model between magnetic force, collision speed, and vehicle mass for theoretical support. Second, based on levitation technology, design the physical structure of the automotive magnetic levitation anti-collision device to ensure efficient anti-collision and normal vehicle driving. Then, develop an intelligent control system to monitor the vehicle's surroundings in real time and adjust magnetic output dynamically for adaptive anti-collision. Finally, verify and optimize the system's performance through computer simulation and physical model tests. In the simulation, construct a multi-scenario virtual model to evaluate key performance indicators. In the real vehicle test, select typical models, conduct

controlled crash tests, compare measured data with simulation results, and optimize system parameters and control strategies to ensure actual application effect and reliability.

2.1. Research Content

The physical mechanisms and key factors of collision formation are mainly reflected in the following three aspects: First, the phenomenon of relative motion imbalance. When the object in front (such as a vehicle or obstacle) decelerates sharply or comes to a standstill, the vehicle behind maintains its original speed due to inertia, resulting in a shortened relative distance between the objects in front and behind, eventually exceeding the threshold of the safe braking distance. The second is the driver's reaction delay. The reaction time from hazard perception to braking execution (0.5-2 seconds) is the decisive stage in the occurrence of a collision. If the vehicle travels a distance beyond the safety buffer range during this period, the risk of collision will increase significantly. The third is environmental and perceptual limitations. Structural flaws such as blind spots in side rearview mirrors can lead to omissions in obstacle detection; Special weather conditions such as night, rain and fog can compress the visual perception range and prolong the effective reaction time.

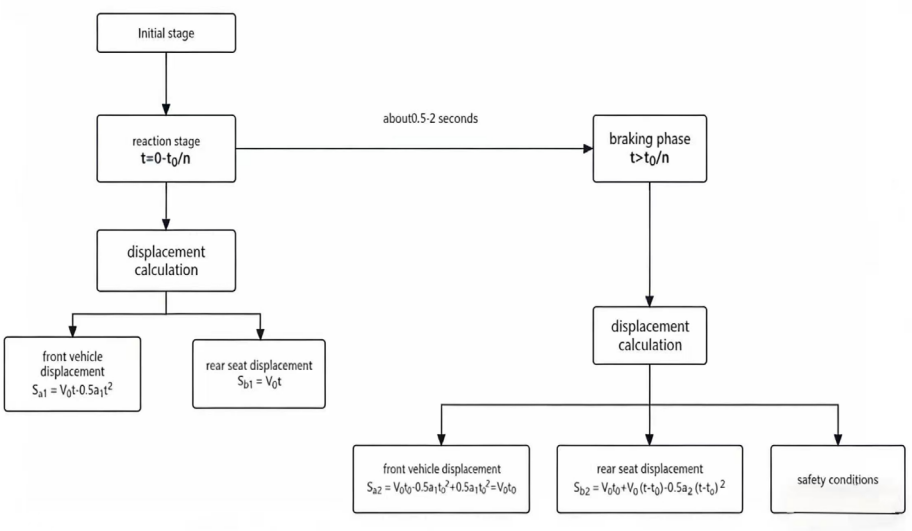


Figure 1. Calculation diagram of the braking state process

2.2. Typical collision scenarios

Collision risks stem from three aspects[1]: When the front object (such as a vehicle or obstacle) decelerates sharply or stops, the rear vehicle maintains its speed due to inertia, shortening the relative distance and exceeding the safe braking threshold. Second, the driver's 0.5-2 seconds reaction delay (from hazard perception to braking) is decisive; traveling beyond the safety buffer during this period raises collision risk. Third, environmental and perceptual limitations: side rearview mirror

blind spots cause obstacle detection omissions, and bad weather compresses visual range and prolongs reaction time.

2.3. Anti-collision safety zone

The time dimension is the critical time threshold for avoiding collisions. The collision time (TTC) is the remaining time for two vehicles to collide if the current speed remains unchanged. The risk of collision increases sharply when the TTC is less than 2 seconds[2], and the ideal safe range is when the TTC is greater than or equal to 2 seconds. Accident time (TA) is the remaining time for successfully avoiding a collision. TA < 1.5 seconds is considered a serious collision, and the reasonable range is TA $\geqslant$ 1.5 seconds.

The motion state dimension is the speed and deceleration rate threshold. Collision avoidance deceleration (DRAC) is the minimum deceleration rate a vehicle needs to avoid a collision. Emergency braking is required when DRAC is greater than $0.15m/s^2$, and the ideal range is DRAC$\leqslant$ $0.15m/s^2$. Conflict speed (CS) is the speed at the moment before the conflict occurs.The severity of the collision increases significantly when CS > 40km/h[3], and it is recommended to keep CS $\leqslant$ 40km/h.

Table 1. Comprehensive Safety performance range for multiple indicators

Indicators	Safe range	Risk interval
TTC	≥2 s	<2 s
TA	≥1.5 s	<1.5 s
DRAC	$0.15m/s^2$	$>0.15m/s^2$
CS	≤40km/h	>40km/h

Upon image input, the system initially performs feature extraction through the backbone module. Specifically, the CBS module generates a 2x downsampled feature map, which is further processed into a 4x downsampled feature map by means of a 2-step convolution kernel. Subsequently, the system alternately employs the E-ELAN efficient aggregation network and the MP module for feature extraction, where the outputs of three E-ELAN modules are utilized as multi-scale input features for the Neck network.

Within the Neck module, the SPPCSPC module first distributes multi-scale feature information across feature maps of different sizes. These multi-scale features are then fused to improve the model's receptive field and enrich its feature representation capability. Thereafter, the fused output is further processed by integrating a pyramid attention network and a feature pyramid network[4].

The input image undergoes two stages of feature extraction (Backbone and Neck) with varying scales and intensities, then integrates through 1×1 convolution before being processed by the Head module for output. This embedded platform achieves blind-spot vehicle detection with over 95% accuracy and 33fps frame rate, delivering warnings up to 2 seconds ahead (TTC safety zone) to extend safety buffer time. The collision mechanism stems from the mismatch between relative motion parameters and driver reaction time[5]. By quantifying Time to Collision (TTC/TA),

Collision Speed (CS), and Deceleration Rate (DRAC), the system defines safety zones as illustrated in Figure 3. Warning technologies (e.g., PFCW/FCW) maintain vehicles within safe zones by extending safety time and reducing collision velocity, significantly lowering collision risks.

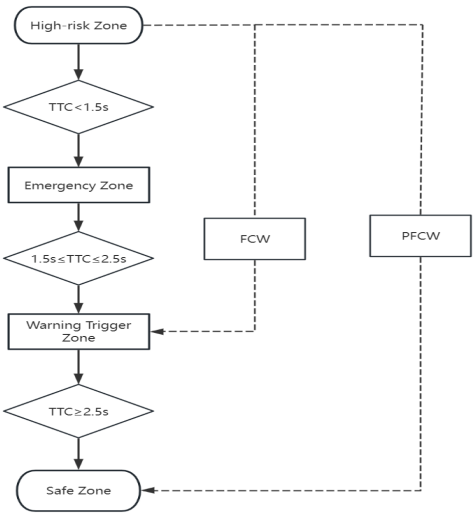


Figure 2. Risk intervals

2.4. Electromagnetic repulsion and levitation theory anti-collision studies

1. Active Collision Avoidance Systems: The on - board electromagnetic device (e.g., a superconducting coil) is connected to the road sensing system, and the electromagnet array accomplishes the levitation mode. In combination with sensor devices such as infrared and image sensors, the distance and trajectory of the vehicle are monitored in real - time[6]. When a collision risk emerges, an electromagnetic repulsive force centered around the in - vehicle controller is generated to alter the vehicle speed. Alternatively[6], the inertial impact is counteracted by the electromagnetic forces on the left and right sides of the vehicle body to modify the vehicle's trajectory.

The collision avoidance system operates through three key stages: First, the environmental perception module uses onboard sensors (e.g., LiDAR and cameras) to continuously monitor road conditions, vehicle spacing[7], and obstacles. Next, the decision-making module employs AI algorithms to analyze data, assess collision risks, and calculate optimal avoidance paths. Finally, the execution module adjusts coil currents to modulate electromagnetic repulsion[8], either increasing or decreasing the repulsive force between vehicles to alter their trajectories. In emergencies, the system instantly elevates the suspension height or intensifies repulsion to prevent direct collisions.

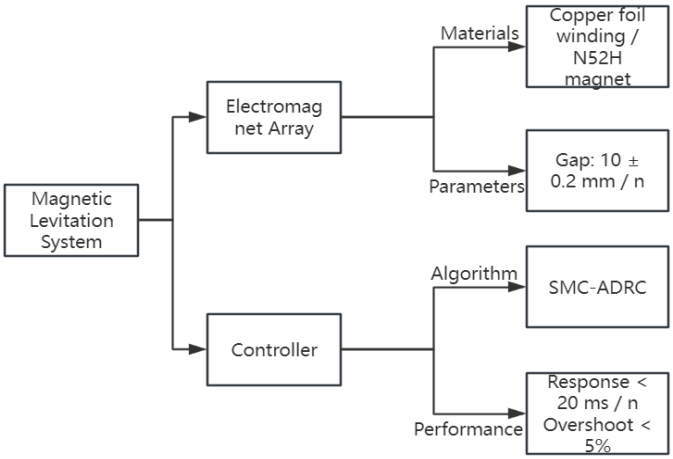


Figure 3. Magnetic Levitation system

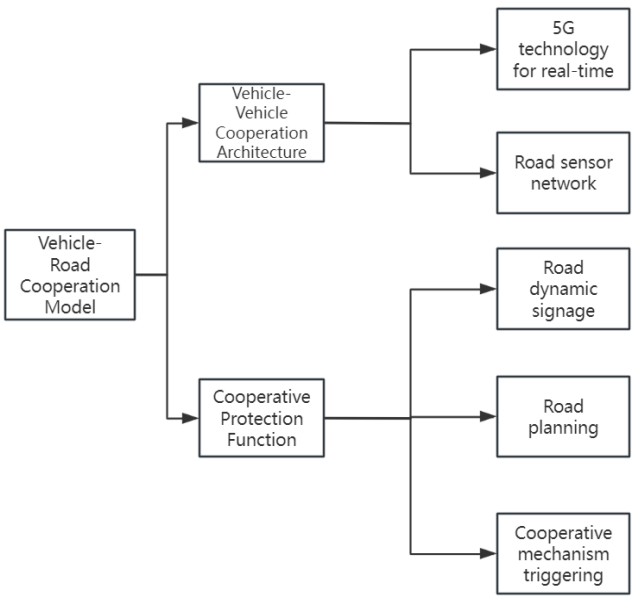


Figure 4. Vehicle anti-collision model

2. Emergency Suspension Buffering: In the event of a collision, the electromagnetic levitation device is activated, and magnetic damping is applied to the vehicle body to mitigate rigid impacts. Similar to maglev trains, this approach necessitates high - precision sensors and millisecond - level response control systems.

3. Multi - level Protection System: Non - contact protection employs electromagnetic repulsion to avert collisions, thereby reducing the probability of collisions[9]. Physical protection integrates with traditional safety systems to provide multi - level safeguards.

4. Design Predominantly Based on Anti - collision Modules:

-- Monitoring: For medium - long distances, the vehicle's supplementary radar and unmanned sensors are used for identification. For medium - short distances, the

camera is employed to monitor and measure data, which is processed by FPGA for rapid response and to generate electromagnetic levitation.

-- Anti-collision: An electromagnetic arrangement is configured around the vehicle. In a head - on scenario, electromagnetic excitation generates a compressed levitation effect to adjust the path or achieve levitation. In the absence of magnetic levitation, the internal electromagnetic dampers generate magnetic resistance and cut coil resistance for emergency braking.

2.5. Vehicle-road coordination electromagnetic section

Build an "electromagnetic road neural network" by embedding a high-density electromagnetic coil matrix beneath the road surface. The coil units have a dual function: one is energy transmission, that is, by using an alternating magnetic field to provide dynamic wireless charging for electric vehicles in motion (refer to the 400-meter wireless charging road pilot project in Michigan, USA), with a charging power of more than 19Kw which can ensure stable energy replenishment for vehicles at a speed of 30km/h. The second is data interaction. The coil acts as a roadside communication node and uses electromagnetic induction modulation technology to conduct two-way data transmission with on-board sensors. For example, the electromagnetic receivers on the vehicle chassis can simultaneously obtain real-time information about the road (such as lane line accuracy, obstacle distribution, electromagnetic radiation levels, etc.) while receiving energy, with data transmission rates of up to 10Mbps or more.

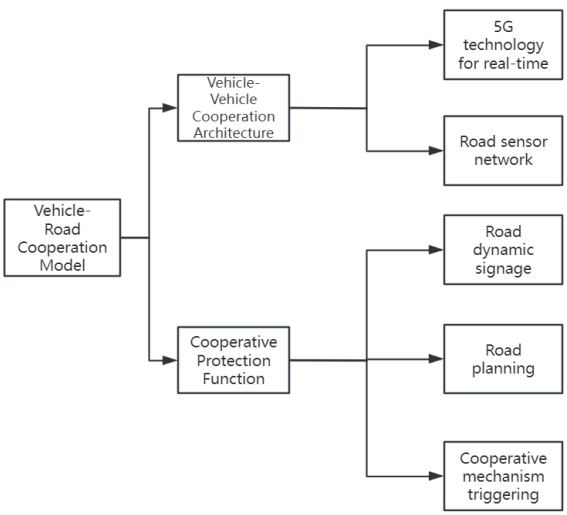


Figure 5. Vehicle-road cooperation model

In addition, vehicles are equipped with high - frequency millimeter - wave radars and electromagnetic identification modules to build a triple perception system. First, environmental perception: the radar scans road - surface electromagnetic tags to identify lane boundaries and traffic - sign electromagnetic codes with centimeter - level positioning. Second, interference warning: on - board electromagnetic sensors

monitor the surrounding electromagnetic environment in real time, using deep - learning models to identify strong electromagnetic areas in advance and optimize driving paths. Third, collaborative decision - making: vehicles interact with electromagnetic roadbeds to get road rating information and optimize autonomous driving strategies, like reducing speed or switching communication frequency bands on high - interference sections.

3. Experimental Design and verification

3.1. Simulation environment and experimental design

There are three different types of operating modes for the system. Specifically, Mode 1 is the anti-collision mode, which is activated when the distance S between vehicles is greater than 0.5 meters. Its main working principle is to use magnetic force to prevent collisions between vehicles. Through the repulsive force generated by the magnetic force and other effects, vehicles maintain a safe driving distance, thereby effectively preventing collisions. Mode 2 is the bounce mode, which comes into play when the distance S between vehicles is exactly 0.5 meters. After the collision occurs, the system will push the vehicles away with the maximum magnetic force, using the powerful magnetic force to instantly push the approaching vehicles away to reduce the potential damage caused by the collision. Mode 3 is the recovery mode. When the distance S between the vehicles is greater than 5 meters after the vehicles have bounced away, the system reverts to the anti-collision mode and re-enters the vehicle collision prevention working state.

Before conducting relevant experiments,a series of preparatory works were carried out. First, a vehicle model was constructed based on Table 2 to simulate the actual vehicle's performance.Meanwhile,an experimental environment was set up according to Table 3 to create a suitable scenario. Then, six different types of collision simulation experiments were conducted in sequence. The first was the car collision test to explore scenarios and data; followed by experiments on small - medium vehicle collisions, small - large vehicle collisions, mid - sized vehicle collisions, mid - large vehicle collisions, and large vehicle collisions to examine phenomena, characteristics,conditions,manifestations,and states respectively. Through these six experiments, a comprehensive and in - depth study of different vehicle collisions was carried out.

Table 2. Vehicle Model Parameters for Small Cars, medium cars and large Cars

	Mass	Maximum magnetic force	Initial distance	Speed interval
Small Cars	1000kg	8000N	30m	5~25m/s
Medium Cars	2000kg	15000N	30m	5~25m/s
Large Cars	4000kg	25000N	30m	5~25m/s

Table 3. Other Settings for the simulation environment

Air density	Drag coefficient	Rolling resistance coefficient	Safety threshold	Gravitational acceleration	Vacuum permeability
1.225 kg/m	0.3	0.001	0.5 m	9.81 m/s	4*pi*1e-7

3.2. Simulation Results

In this study,matlab was used to simulate and verify the scenarios in the above table. matlab simulation diagrams of the magnetic levitation anti-collision system with post-collision bounce function in each scenario are shown below.

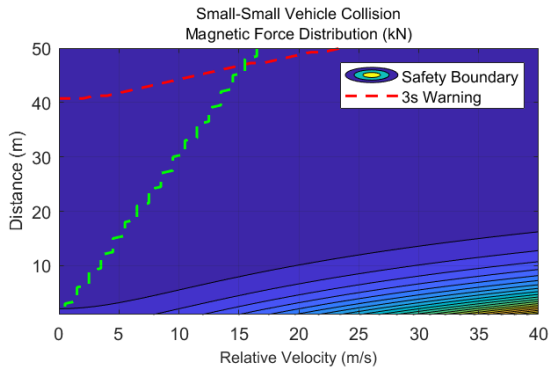


Figure 6. Small-Small Vehicle Collision Magnetic Force Distribution

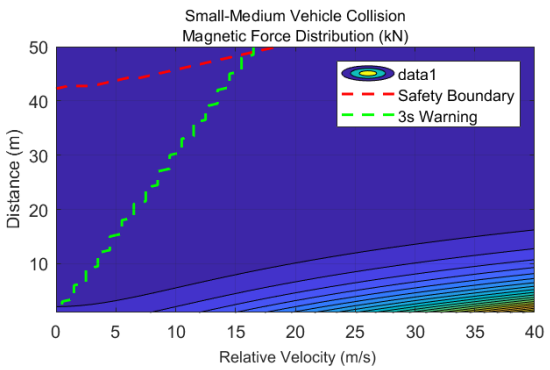


Figure 7. Small-Medium Vehicle Collision Magnetic Force Distribution

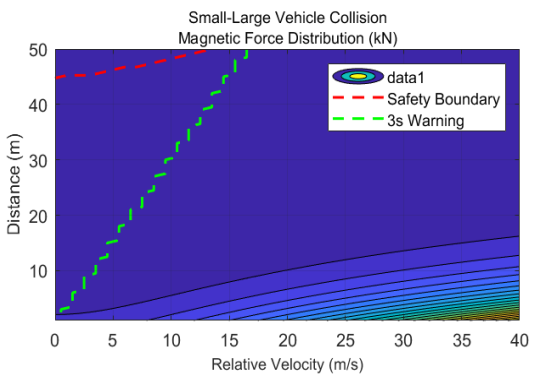


Figure 8. Small-Large Vehicle Collision Magnetic Force Distribution

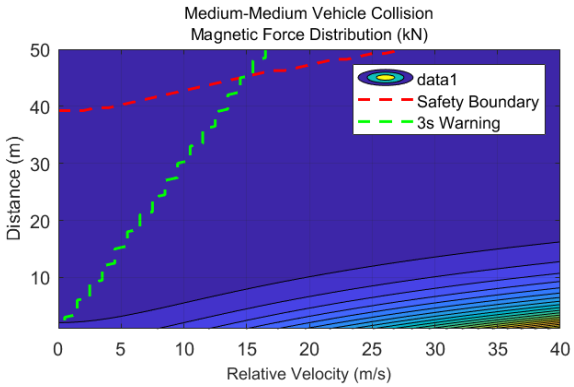


Figure 9. Medium-Medium Vehicle Collision Magnetic Force Distribution

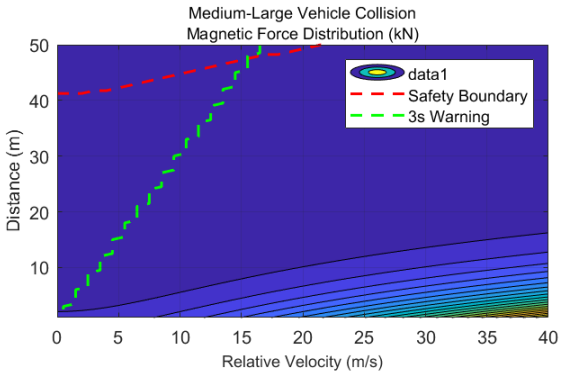


Figure 10. Medium-Large Vehicle Collision Magnetic Force Distribution

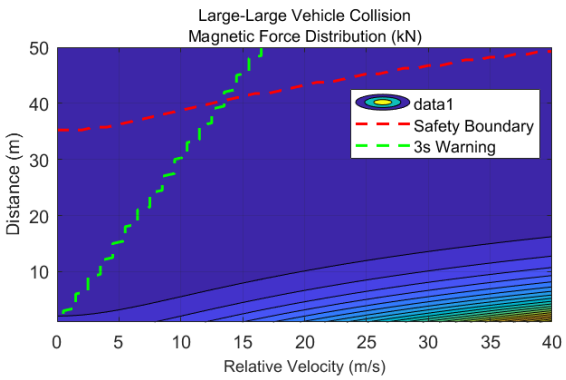


Figure 11. Large-Large Vehicle Collision Magnetic Force Distribution

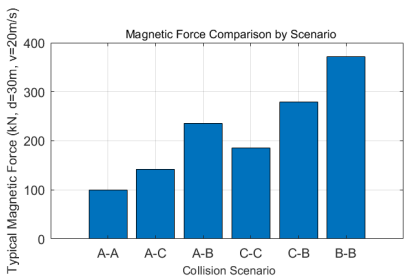


Figure 12. Magnetic Force Comparison by Scenario



Figure 13. Safety Distance Requirements by Scenario

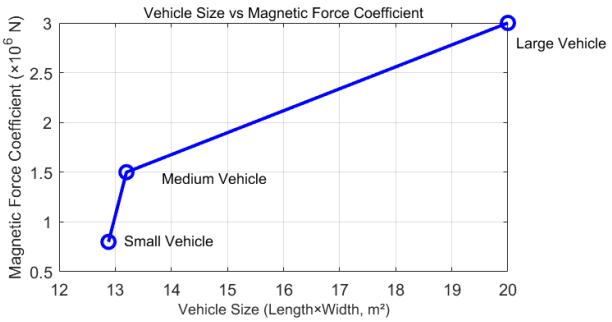


Figure 14. Vehicle Size vs Magnetic Force Coefficient

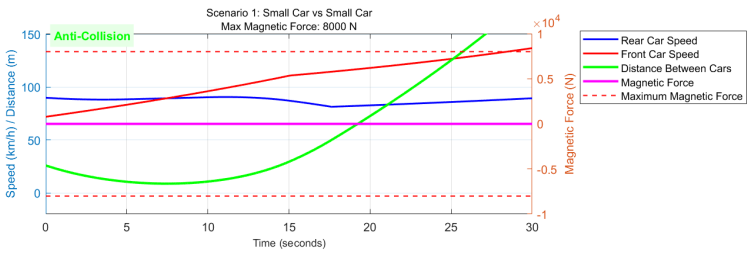


Figure 15. Scenario 1: Small Car vs Small Car

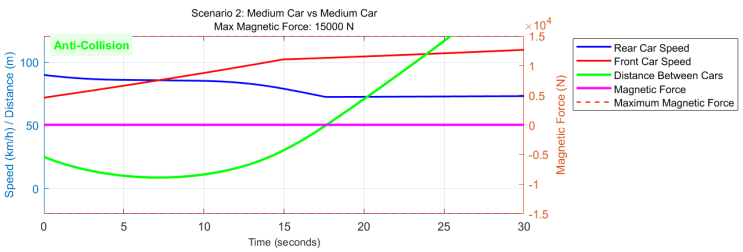


Figure 16. Scenario 2: Medium Car vs Medium Car

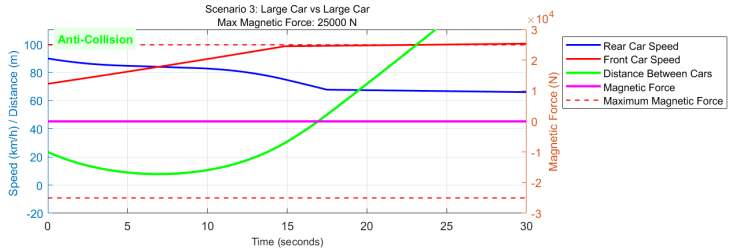


Figure 17. Scenario 3: Large Car vs Large Car

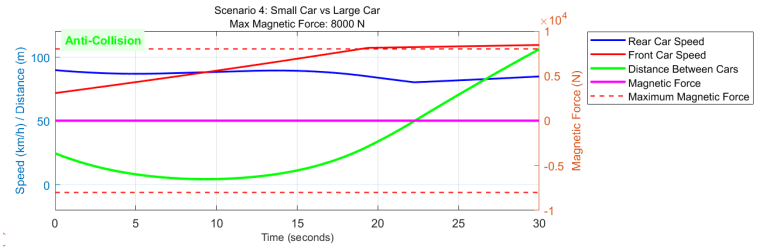


Figure 18. Scenario 4: Small Car vs Large Car

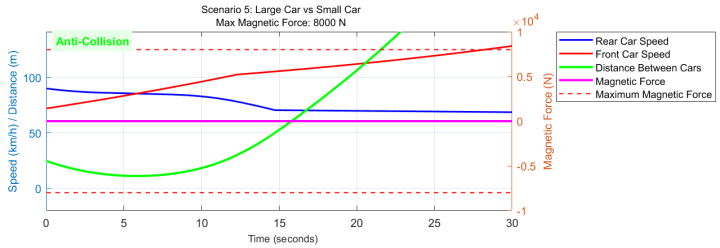


Figure 19. Scenario 5: Large Car vs Small Car

From the relationship curve between magnetic force and distance presented in the aforementioned figures, it is evident that when the distance between the two vehicles is relatively short, the magnetic force demonstrates a non-linear and rapid increase as the distance diminishes. This phenomenon provides a theoretical basis for the prompt provision of a strong braking force at short distances. When the distance is relatively large, the magnetic force shows a tendency to stabilize, which effectively reduces unnecessary energy dissipation over long distances. The collision depth data in each scenario further verified the effectiveness of the magnetic levitation anti-collision system. Under the predefined simulation parameters, the collision depth in all scenarios was zero, indicating that the system can effectively buffer and prevent significant collisions via magnetic repulsion before they occur.

A detailed comparison of the various scenarios clearly shows that when the differences in mass and magnetic moment between vehicles in the forward and backward driving state are smaller, the deceleration process of the vehicle becomes smoother under the effect of magnetic repulsion. As the deceleration becomes more gentle, the safe distance between vehicles will also decrease accordingly. However, when the heavier vehicle is driving behind, it is necessary to activate the magnetic braking force earlier for safety purposes to ensure safety throughout the driving process.

4. Conclusions

This study focuses on the cross-scenario innovative application of electromagnetic technology in intelligent transportation systems.Through theoretical modeling, system architecture design and multi-platform simulation verification, it systematically explores its application potential and technological breakthroughs in

four core dimensions: dynamic energy replenishment, complex environment adaptation, traffic coordination control, and active safety protection.

In the domain of dynamic charging and energy efficiency optimization,a"vehicle-stop coordinated energy replenishment based on electromagnetic induction" scheme is put forward to address the range - related challenges of frequently operating vehicles such as buses and logistics vehicles. High - power charging coils are installed at crucial nodes like transportation hubs and stations to rapidly replenish energy for vehicles during their temporary halts. A dynamic optimization model for driving strategies is established by integrating real - time energy consumption data from electromagnetic roadbeds, with a focus on enhancing the efficiency of braking energy recovery. Simulation results verify that this scheme can elevate the overall energy efficiency of the system by 15% - 20%, effectively alleviating the range anxiety of electric vehices.

Regarding the enhancement of safety in complex environments, a collaborative perception system of millimeter-wave radar and electromagnetic tags is constructed to guarantee the stability and accuracy of lane identification under extreme weather conditions, including heavy rain and thick fog. A road electromagnetic interference rating and early - warning system is developed to forecast high - risk areas and offer dynamic path guidance based on historical data. A multi - level electromagnetic shielding structure for vehicles is designed to effectively resist strong electromagnetic pulse interference from the external environment and ensure the reliable operation of on - board electronic systems in complex electromagnetic settings.

At the level of intelligent transportation collaborative control, relying on core data such as vehicle trajectory and speed captured in real-time by the electromagnetic roadbed, dynamic optimization of signal timing and intelligent congestion alleviation are realized through edge computing nodes. An emergency response mechanism for communication interruption is established to support the system in automatically switching to the direct - connection control mode of the roadbed, ensuring the priority passage rights of emergency vehicles. Dynamic warning devices are triggered via electromagnetic signals to rapidly construct virtual traffic isolation belts in accident or construction areas, thereby simultaneously improving traffic efficiency and safety levels.

In conclusion, through multi - dimensional technological innovation and empirical analysis, this study validates that electromagnetic technology can offer core technical support for the efficient, safe, and intelligent upgrade of intelligent transportation systems in key aspects such as energy management, environmental adaptation, cooperative control, and safety protection. Its extensive application scenarios and significant technical advantages provide important references for technological innovation and industrial development in the transportation field in the future.

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