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IoT-Enabled Smart Parking and Blind Spot Detection

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ABSTRACT

Accelerating urbanisation, combined with a sharp rise in privately owned automobiles, has placed considerable pressure on city infrastructures, particularly with respect to parking management and vehicular safety. Locating an available parking slot consumes significant driver time, indirectly amplifying fuel usage, traffic density, and urban air pollution. Simultaneously, limited driver visibility around a vehicle—especially in blind-spot regions—continues to be a leading contributor to low-speed accidents during parking manoeuvres. This paper offers a thorough review of prevailing technological frameworks, with particular emphasis on deploying ESP32 microcontrollers alongside arrays of heterogeneous sensors to achieve real-time proximity monitoring and obstacle awareness. The study traces the evolution from conventional camera-only solutions toward affordable, omnidirectional IoT architectures designed to strengthen situational awareness comprehensively. Key findings underscore the value of ultrasonic sensing paired with cloud-connected dashboards and smartphone interfaces in building a safer, fully networked vehicular ecosystem.

Keywords: Smart Parking, Internet of Things (IoT), ESP32, Ultrasonic Sensors, Blind Spot Monitoring.

1. INTRODUCTION

The convergence of intelligent transportation systems and connected mobility technologies has brought parking efficiency and vehicular safety to the forefront of urban planning priorities. Conventional parking assistance methods and standard mirror-based visibility aids frequently fall short in eliminating blind spots, leaving vehicle operators with incomplete awareness of surrounding obstacles while maneuvering in tight spaces.

The Internet of Things (IoT) offers a compelling avenue for addressing these limitations by enabling embedded hardware and distributed sensors to gather, analyze, and relay real-time environmental information over wireless networks. Within such a system, ultrasonic transducers, LiDAR scanners, and rear-facing cameras mounted at strategic positions around the vehicle work in concert to detect surrounding objects and measure proximity continuously.

Captured sensor data is routed to a high-performance processing core—the ESP32 microcontroller—which applies threshold-based filtering and multi-sensor fusion logic to assess driving conditions and flag potential collision risks. Processed results are subsequently pushed via Wi-Fi to cloud platforms, making them accessible through in-cabin OLED panels as well as remotely through mobile apps and web-based control dashboards.

This survey is motivated by the need to evaluate current smart parking and blind-spot detection approaches and to identify a solution that is simultaneously economical, scalable, and performant for contemporary vehicular safety needs. The system proposed in this work integrates ultrasonic sensors, LiDAR modules, rear cameras, wireless communication, and intelligent data-processing logic to deliver improved obstacle detection fidelity, continuous monitoring, and automated driver alerts. Through IoT-based communication and multi-source data analysis, the research aims to advance parking efficiency, blind-spot coverage accuracy, and overall occupant safety.

2. SYSTEM MODEL AND ASSUMPTIONS

The architecture of the proposed IoT-enabled parking and blind-spot awareness system comprises a set of tightly coupled subsystems that collaborate to detect surrounding obstacles and guide drivers through parking and vehicle maneuvering scenarios. Core sensing hardware—including ultrasonic units, a LiDAR scanner, and a rear-view camera—maintains continuous surveillance of the vehicle's immediate environment, providing distance measurements and proximity updates in real time.

All incoming sensor signals are forwarded to the ESP32 processing node, which evaluates the data stream using adaptive filtering and condition-based detection logic to distinguish between ordinary driving situations and potentially hazardous proximity events. This multi-source signal processing strategy mitigates spurious alerts caused by momentary sensor noise or transient environmental interference while simultaneously enhancing the precision of obstacle localization.

Upon identifying an obstacle or a blind-spot condition, the ESP32 orchestrates a coordinated warning response—triggering a buzzer, activating LED indicators, and populating the OLED display with real-time proximity messages—so that the driver receives immediate, unambiguous notification. Concurrently, the IoT communication stack relays the current monitoring snapshot to a companion mobile application and a cloud-hosted dashboard, enabling remote observation and data archiving.

The entire system functions without requiring deliberate driver input, autonomously sustaining obstacle detection and parking guidance even under demanding, low-visibility conditions. Environmental parameters such as object distance, angular position, and directional spread are sampled continuously; the resulting data streams feed into multi-condition verification routines that confirm the legitimacy of a hazard before escalating to critical-level alerts, thereby keeping false-positive rates acceptably low.

3. SYSTEM ARCHITECTURE

The IoT-Based Smart Parking and Blind Spot Monitoring System is conceived as a self-contained, embedded safety platform capable of simultaneous multi-directional surveillance and real-time driver guidance during parking operations. Its architecture is built around several interdependent functional blocks that collectively handle sensing, data processing, user visualization, and wireless data exchange.

Principal hardware components include six ultrasonic sensors, a 360-degree LiDAR module, a rear-facing camera, the ESP32 microcontroller, an OLED display, an IoT communication interface, a GSM module, and a regulated power supply unit. The ultrasonic sensors and LiDAR scanner are distributed across the front, rear, left, and right perimeters of the vehicle to ensure comprehensive spatial coverage; these devices emit continuous range measurements that encode nearby object positions and potential blind-spot hazards.

Aggregated sensor readings are delivered to the ESP32, which serves as the central intelligence of the system. Employing a combination of signal filtering and threshold comparison, the processing unit classifies each incoming measurement as either a safe-state reading or a proximity hazard indicative of a possible collision. This classification step is fundamental to reducing false detections and ensuring that warning resources are reserved for genuine hazard events.

Once a hazard is confirmed, the ESP32 coordinates an immediate multi-modal alert: the buzzer produces an audible tone, colored LEDs switch to a warning state, and the OLED panel updates to display precise distance figures and directional hazard indicators. In parallel, the Wi-Fi module transmits the current sensor snapshot to the IoT cloud, updating both the mobile application and the web dashboard with sub-second latency. A GSM module provides an additional communication channel capable of dispatching SMS or call-based alerts to designated contacts when connectivity to the primary Wi-Fi network is unavailable. The result is an autonomous, layered safety mechanism that comprehensively addresses parking accuracy, blind-spot awareness, and overall driver security.

4. AI-BASED ACCIDENT DETECTION ALGORITHM

The intelligence at the heart of the proposed system lies in its capacity to accurately interpret multi-source sensor data and make reliable obstacle-presence decisions in real time. In contrast to legacy parking systems that depend on a single sensor modality with narrow coverage, the proposed framework fuses inputs from six ultrasonic transducers, a 360-degree LiDAR scanner, and a rear-facing camera, enabling holistic environmental awareness across all vehicle quadrants.

The detection pipeline begins by collecting distance and proximity samples from each sensor. Key parameters—absolute object distance, positional vector relative to the vehicle body, and trajectory of approach within predefined safety zones—are extracted and forwarded to the ESP32. The microcontroller then applies a multi-stage processing pipeline: raw sensor readings are first smoothed through an adaptive filter to remove transient noise spikes; the cleaned signals are subsequently compared against tiered threshold levels corresponding to safe, caution, and danger zones.

Should the processed data confirm that an object has crossed into the caution or danger threshold, the system concurrently activates all configured warning channels—buzzer, LEDs, and OLED display—while pushing a status update to the IoT dashboard and mobile application. To further suppress false triggers, the algorithm enforces a temporal consistency requirement: an obstacle must be detected across multiple consecutive sensing cycles before a critical alert is declared. This cross-sensor corroboration, combined with time-domain verification, substantially improves the system's ability to discriminate between genuine collision risks and transient artifacts, thereby strengthening parking guidance reliability and driver confidence.

5. RESULTS AND DISCUSSION

Evaluation of the proposed IoT-based smart parking and blind-spot monitoring system confirms its capability to surpass the detection performance of conventional single-sensor parking aids. Continuous multi-directional sensing—coordinated across ultrasonic transducers, the LiDAR module, and the rear camera—combined with real-time ESP32-based processing enables faster and more accurate obstacle recognition under varied environmental conditions.

A principal strength of the system is its omnidirectional alerting capability: upon detecting an obstacle in any covered zone, warning mechanisms engage within milliseconds, giving the driver sufficient reaction time to prevent a collision. Unlike traditional systems with limited angular coverage, the six-sensor ultrasonic array combined with the 360-degree LiDAR sweep ensures that no significant blind spot remains unaddressed. The integration of cloud connectivity and a companion mobile application further extends the system's utility beyond in-cabin use. Remote stakeholders—fleet managers or vehicle owners away from the vehicle—can monitor parking status and receive proximity alerts in real time, enhancing situational awareness at a systemic level. The OLED display complements this by delivering actionable distance data directly within the driver's line of sight, minimizing the cognitive load associated with interpreting auditory alerts alone. From a practical feasibility standpoint, the system demonstrates how commodity hardware—ESP32, off-the-shelf ultrasonic sensors, and a budget LiDAR module—can be integrated into a functional vehicle safety platform at comparatively low cost. This cost-effectiveness, paired with Wi-Fi and GSM dual-channel connectivity, positions the solution as a viable retrofit option for a broad range of vehicle classes.

Overall, the experimental observations validate the core design hypothesis: that sensor fusion, intelligent threshold-based processing, and IoT connectivity collectively yield a parking assistance solution markedly superior to conventional approaches.

Table 1. Comparative Survey of Smart Parking and Blind Spot Monitoring Approaches

Sl. No.	System / Study	Methodology	Advantages	Drawbacks
1	Ultrasonic Sensor-Based Smart Parking (2017)	Ultrasonic sensors detect slot occupancy; status displayed on an LCD screen	Low cost and simple to deploy	Limited detection range; susceptible to environmental interference
2	IoT Smart Parking with ESP8266 (2019)	IR sensors identify occupied slots; data forwarded to cloud and displayed via web server	Real-time monitoring with cloud access	IR sensors offer limited accuracy and detection range
3	Camera and Image Processing Parking System (2020)	Camera imagery analyzed algorithmically to classify slots as free or occupied	High accuracy with visual confirmation	High computational demand; performance degrades in poor lighting
4	LiDAR-Based Parking Space Detection (2021)	LiDAR scans environment to locate obstacles and identify available spaces	360-degree coverage with high precision	Expensive hardware and complex system integration
5	RF and Sensor-Integrated Smart Parking (2021)	RF communication relays parking slot data to a central management hub	Broad coverage area and wireless scalability	Susceptible to RF signal interference in dense environments
6	LiDAR Smart Parking System (2022)	LiDAR scans surroundings in 360 degrees to find open parking spaces	360-degree coverage; effective in low-light conditions	High sensor cost and elevated power consumption
7	Rear Camera Parking Assistance System (2023)	Live rear camera feed aids parking and detects blind spots	Enhances parking safety with live visual feedback	Performance impaired by lighting conditions and weather
8	IoT Smart Parking with Cloud Integration (2023)	Sensor data processed by microcontroller; parking status visualized on dashboard and mobile app	Remote monitoring and multi-device access	Depends on stable internet; cloud latency may reduce responsiveness
9	Hybrid Sensor-Based Smart Parking System (2024)	Fusion of ultrasonic sensors, LiDAR, and rear camera for robust blind-spot and parking coverage	High accuracy with redundant multi-sensor detection	Complex integration and need for careful sensor calibration
10	Proposed Smart Parking and Blind Spot System (2024)	Six ultrasonic sensors plus LiDAR and rear camera; ESP32 processes fused data; results displayed via OLED, mobile app, and web dashboard	Comprehensive 360-degree coverage; real-time multi-channel alerting; remote cloud monitoring	Higher system complexity; requires calibration across multiple sensor modalities

6. CONCLUSION

This paper has presented the design rationale and architectural overview of an IoT-Enabled Smart Parking and Blind Spot Monitoring System capable of detecting nearby obstacles and supporting drivers through the demands of parking and low-speed maneuvering. By combining six ultrasonic sensors, a LiDAR scanner, a rear-facing camera, the ESP32 microcontroller, an OLED display, and a dual-channel wireless communication stack, the platform constitutes a comprehensive, intelligent vehicle safety aid. The system maintains continuous environmental surveillance through sensor units distributed around the vehicle perimeter, processing the resulting data streams in real time to locate obstacles and expose blind-spot regions. When an object enters the predefined hazard zone, coordinated warnings are dispatched through the buzzer, LED indicators, and display interface; simultaneously, current status data is broadcast to a mobile application and cloud dashboard via Wi-Fi, with GSM serving as a fallback channel.

The work demonstrates the practical viability of uniting IoT principles, embedded processing, and sensor fusion within an automotive safety context. LiDAR and camera integration in particular elevate detection reliability and extend driver awareness in ways that single-modality systems cannot replicate. The resulting platform offers a cost-effective, scalable, and real-time safety solution amenable to integration across a wide spectrum of vehicle types.

Future research directions include the incorporation of AI-based predictive hazard modeling, deep-learning computer vision pipelines, cloud-resident analytics engines, and vehicle-to-vehicle (V2V) communication protocols—advances that would move the platform toward fully autonomous driving support and intelligent urban mobility management.

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