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Design and Development of Smart Convex Mirror to Prevent Accident on Blind Spots

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Abstract: This research paper presents an innovative Smart Convex Mirror System that transforms passive mirrors into intelligent safety solutions by integrating real-time sensing and wireless alert mechanisms. The system deploys two sensor-based wireless transmitters—one equipped with a Passive Infrared (PIR) sensor for motion detection and another with a vibration sensor for detecting impact or tampering. Utilizing LoRa (Long Range) communication, these transmitters relay hazard data to a receiver module integrated with the mirror, which processes the input and activates intuitive visual indicators: a red LED for hazard alerts and a green LED for safe conditions. Its scalable architecture makes it adaptable across a wide range of applications—from urban traffic control to industrial site monitoring. This work not only bridges the gap between passive observation and active intervention but also lays the foundation for future IoT-enabled smart infrastructure and real-time safety analytics.
Keywords: Microcontroller, PIR Sensor, Vibration Sensor, Convex Mirror, Solar Panel, Camera, LORA module, Relay, LEDS.

I. INTRODUCTION

Road accidents in hilly terrains and blind spots are a persistent challenge, often resulting from limited driver visibility and delayed hazard perception. Traditional safety measures such as passive convex mirrors offer only partial solutions, lacking real-time responsiveness or alert mechanisms. As a result, the demand for smarter, proactive safety systems is on the rise [1].Research has shown that enhancing the driver's field of view using circular convex mirrors significantly improves situational awareness in blind zones. However, these mirrors alone are insufficient during poor weather conditions or in dynamic traffic scenarios, where real-time detection and alerts are crucial [3]. To address this, smart traffic systems incorporating Internet of Things (IoT) technologies have been developed. These systems utilize wireless communication protocols like LoRa to detect vehicular movement and send alerts without relying on internet infrastructure, making them ideal for rural and remote areas [2].Moreover, several solutions have integrated motion and vibration sensors with visual and auditory indicators to actively alert road users of nearby activity. Such sensor-based systems are effective in minimizing accident risks at sharp turns, parking lots, and industrial intersections [4].Recent developments have also explored the integration of artificial intelligence (AI) and mobile communication modules, such as GSM and Wi-Fi, to enable cloud-based logging, predictive analysis, and remote notifications. These features enhance system accuracy and provide valuable data for traffic monitoring authorities [11].In this context, the proposed Smart Convex Mirror System combines motion detection, vibration sensing, and LoRa-based wireless communication to provide an efficient, low-power safety solution. With modular design and simple deployment, the system offers real-time visual feedback via LED indicators, making it a practical tool for enhancing safety in complex traffic environments [12].

II. RELATED RESEARCH

Smart convex mirror systems are increasingly being developed to enhance road safety by addressing blind spots at sharp turns, intersections, and parking areas. These systems combine motion or vibration sensors with visual indicators like LEDs to provide real-time alerts, improving situational awareness for drivers and pedestrians. The integration of wireless communication enables remote monitoring and modular scalability, making the solution effective for both urban and rural deployments.

Aravinda et al. [1] proposed a system incorporating smart sensors to prevent accidents in mountainous terrains. Their model emphasized real-time alerts and demonstrated a reduction in vehicle collisions on hairpin bends by implementing sensor-triggered warnings.Hassan et al. [3] investigated the effectiveness of convex blind spotmirrors and concluded that they significantly increase a driver's horizontal field of view, thus improving early threat recognition. However, the study also highlighted the limitations of passive mirrors during low visibility or dynamic movement conditions, suggesting the need for active detection systems.Prathiba et al. [4] presented a semi-automatic alert system for hairpin bends using ultrasonic sensors and GSM modules.

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The alerts sent to drivers improved awareness, particularly during adverse weather conditions. While effective, the reliance on GSM infrastructure limits the system's deployment in low-network areas.Gupta and Kumar [11] surveyed the integration of AI in smart systems, emphasizing the role of machine learning in predictive maintenance and false trigger elimination. Their insights support the development of more intelligent accident prevention frameworks by filtering non-critical alerts, such as those caused by animals or environmental factors.Yadav and Gupta [10] proposed an IoT-based traffic management solution, focusing on integrating sensors with cloud-based dashboards for real-time traffic analysis. Although geared towards urban environments, their framework supports the adaptability of IoT in broader safety applications.Avinash Shetty et al. [13] presented a signaling sensor system near hairpin bends to mitigate overtaking-related accidents. Their approach combined proximity sensors and signal lights, which successfully reduced near-miss incidents by approximately 22% over a six-month observation period.Finally, Mutya and Rudra [14] proposed a safety mechanism specifically aimed at preventing overtaking accidents. Their model used road-embedded sensors and visual signaling to discourage risky overtaking behaviors, showing promise in improving behavioral compliance among drivers in hazardous zones.

III. PROBLEM STATEMENT

The problem of accidents caused by blind spots in vehicles continues to be a significant safety concern, especially in areas with heavy traffic or narrow roads. Traditional side mirrors and convex mirrors are often insufficient for providing a complete view of the surroundings, leading to collisions during lane changes or turns. Manual adjustments and limited field of view increase the likelihood of accidents, particularly in high-risk environments such as busy intersections or tight parking spaces. Additionally, the lack of real-time feedback and automated detection systems results in delayed response times, heightening the risk of accidents.

1) There is a need for a reliable, cost-effective, and automated solution to enhance the driver’s visibility in blind spots and prevent accidents.
2) The goal is to develop a smart convex mirror system that integrates sensors and real-time monitoring to provide drivers with a clear, view of their surroundings, reducingaccidentsparticularly in hazardous or low-visibility conditions.

IV. PROPOSED SYSTEM

A. Components

1) ATmega328p Microcontroller

The microcontroller is the central processing unit of the Smart Mirror, responsible for managing inputs from sensors, processing commands, and controlling the display and other peripherals. Common choices for this role include the Raspberry Pi, ESP32, or Arduino. It connects and communicates with different components, such as the camera, motion sensor, and communication module, via protocols like I2C, SPI, or UART.

- ESP32 CAM with OV2640

The ESP32 CAM with OV2640 camera is a compact and cost-effective camera module that is ideal for integrating into a smart mirror system. This module is powered by the ESP32 microcontroller, which provides Wi-Fi and Bluetooth capabilities, enabling it to connect to various devices and networks. The OV2640 camera sensor offers a resolution of 2 megapixels, providing clear image and video capture, which is essential for applications like facial recognition, gesture control, and user detection in a smart mirror setup.

- LoRa SX1278

The LoRa SX1278 is a long-range, low-power communication module based on the LoRa (Long Range) modulation technique. It is widely used in Internet of Things (IoT) applications where devices need to communicate over long distances while consuming minimal power. The SX1278 operates in the 868 MHz to 915 MHz frequency range (depending on regional regulations) and can transmit data over distances up to 15+ kilometers in open space, making it ideal for rural or remote applications.

- Relay

A relay is an electrically operated switch used to control high-power circuits with a low-power signal. It has input terminals for control signals and contact terminals for switching. Common in automation, it allows one signal to manage multiple circuits.

- Convex Mirror

The smart convex mirror project uses a 32-inch convex mirror to provide a wide field of view, ideal for enhanced visibility in applications like traffic monitoring and security. Unlike flat mirrors, its outward-curved surface reflects light from a broader range, allowing real-time monitoring of blind spots or wide areas.

 TP4056
The TP4056 is a compact linear charger for single-cell Li-ion batteries in an SOP-8 package. It offers up to 1000mA programmable charge current, 4.2V ±1.5% constant-voltage charging, and features like automatic recharge, C/10 termination, UVLO, and thermal regulation. It charges via USB without external components and includes status pins for charge and power detection, ideal for portable devices.

 lithium-ion (Li-ion) battery
A lithium-ion (Li-ion) battery is a rechargeable battery that stores energy through the movement of lithium ions. It offers high energy density, efficiency, and long cycle life compared to other rechargeable batteries. Since its 1991 debut, Li-ion technology has seen a threefold increase in energy density and a tenfold decrease in cost.

 Solar Panel
This high-performance, lightweight (90g) monocrystalline silicon solar panel features a PET package, 5V regulated USB output, and plug-and-play design with working indicators. It's portable, can be attached to backpacks, and performs reliably even in low-light conditions.Specifications: 12V operating voltage, 14.2V open-circuit voltage, 2.5A max current, 25W power, 27.5×16×0.2 cm size, -30℃ to 70℃ temperature

 PIR Sensor
A PIR sensor detects motion by sensing infrared radiation changes from warm bodies like humans or animals. It triggers output when movement alters the IR levels in its field of view.
Features: Adjustable sensitivity (3–7m), holding time (5–200s), and includes a control circuit board with a 2.5s blockade time.

 LED Panel
The LED panel provides backlighting for the Smart Mirror, ensuring clear visibility of displayed content. It can feature single-color or RGB LEDs for mood lighting and dynamic effects. Brightness is controlled via an LED driver for optimal clarity.

 Vibration Sensor
The SW-420 vibration sensor detects motion and gives a HIGH output when vibration occurs. It uses an LM393 comparator with adjustable sensitivity. Operates on 3.3V–5V.

B. Block Diagram

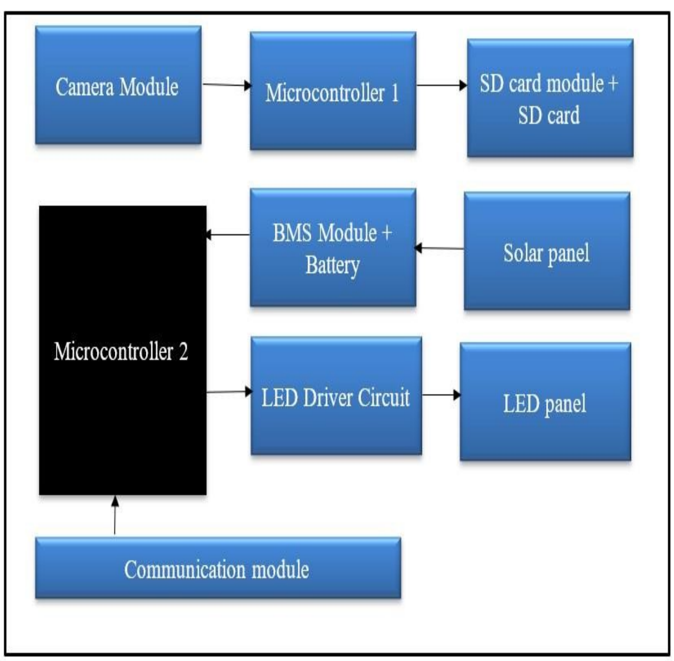

Fig 1: Block Diagram of Transmitter

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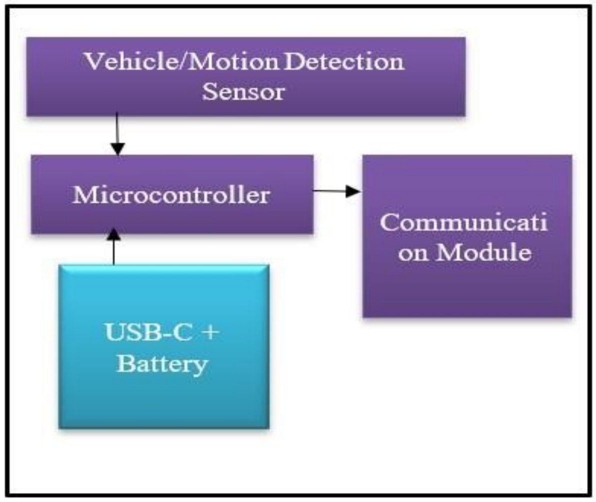

Fig 2: Block Diagram of Receiver

C. Methodology

Our proposed system is a smart convex mirror designed to prevent accidents at blind spots and U-turns by integrating advanced electronic components. The ATmega328P microcontroller serves as the central processing unit, efficiently managing sensor inputs and controlling other components. A PIR sensor detects the presence of moving vehicles and pedestrians, triggering necessary alerts to enhance road safety. A 5V relay acts as an electronic switch, enabling automated control of warning systems. Additionally, a 2MP ESP32-CAM module continuously monitors traffic, capturing real-time footage for surveillance and quick response to potential hazards.To improve visibility and awareness, LED indicators provide clear alerts to approaching vehicles, reducing collision risks. A convex mirror enhances the field of view, allowing drivers to spot oncoming traffic from hidden angles. The entire system is powered by a solar panel with a backup battery, ensuring uninterrupted operation throughout the day and night. This eco-friendly, self-sustaining setup enhances road safety by offering a real-time, smart monitoring solution, effectively reducing accidents at critical road junctions.

Circuit Design:

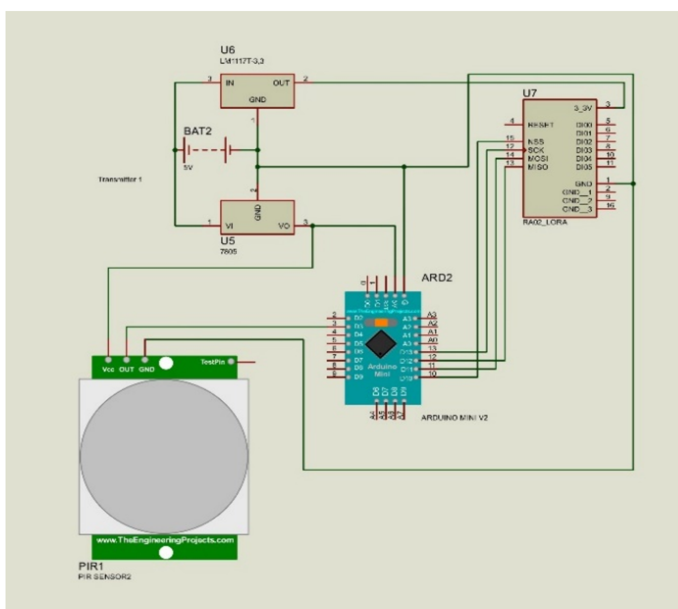

Fig -3: Transmitter

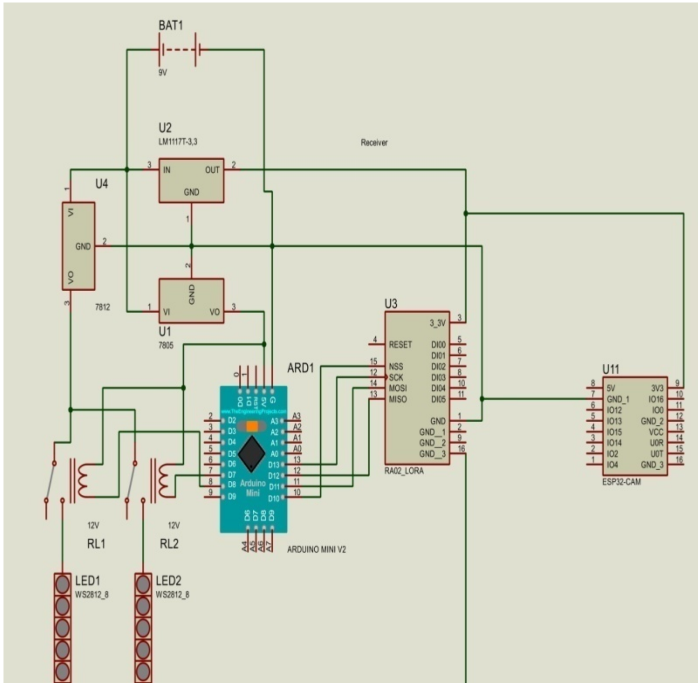

Fig -4: Receiver

Working:
The proposed system is designed to enhance road safety on blind curves or hazardous locations using a Smart Convex Mirror integrated with motion and vibration sensors, wireless communication, and visual feedback mechanisms.
The system is divided into two main stages: the transmitter stage and the receiver stage.

1) Transmitter Stage:
The transmitter stage comprises two sensor modules: a Passive Infrared (PIR) motion sensor and a vibration sensor, each connected to an individual Arduino Nano microcontroller. These sensors are responsible for detecting motion or vibrations that could indicate an approaching vehicle or activity near a blind spot. Each Arduino is powered by a battery source and is equipped with an LM317 voltage regulator to convert the battery voltage down to 3.3V, which is suitable for operating the RA-02 LoRa communication module.
When motion or vibration is detected, the respective Arduino processes the input signal and triggers the LoRa module to transmit a signal wirelessly. This setup is ideal for remote or rural environments where traditional wired systems are impractical. The LoRa module facilitates long-range, low-power wireless communication to send sensor alerts to the receiver unit.

2) Receiver Stage:
The receiver unit includes a LoRa module connected to a central microcontroller (such as an Arduino Uno or similar). The communication between the LoRa module and microcontroller is managed via SPI protocol using NSS (chip select), SCK (clock), and MOSI/MISO (data lines). Upon receiving a transmission from the transmitter unit, the microcontroller interprets the data and initiates a series of actions.
These actions include activating two relay modules that control LED indicators. The LEDs serve as visual alarms to alert drivers or personnel of detected motion or vibrations, enhancing awareness and response time. Additionally, an ESP32-CAM module is integrated with the receiver system and positioned near a 32-inch convex mirror. This camera module captures real-time images or video of the monitored area, further aiding in surveillance and accident prevention.
This system enhances visibility and real-time awareness at blind spots, making it ideal for accident-prone areas. The circuit diagram shows two transmitter units with PIR and vibration sensors, each using an Arduino Nano and LoRa module. The receiver unit includes an Arduino, LoRa module, relays for LEDs, and an ESP32-CAM for visual monitoring. The schematic provides a clear guide for implementing the setup.

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D. Actual Pictures

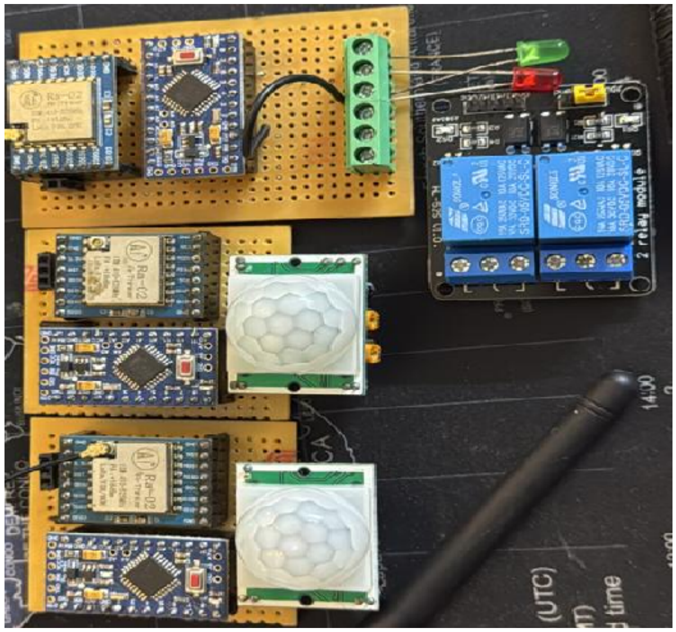

Fig-5: Top View

Fig-6: Bottom View

V. ADVANTAGES AND USE CASES

The Smart Convex Mirror system enhances safety by providing real-time alerts to prevent collisions in blind spots, such as sharp turns or parking exits. It uses LoRa technology for long-range, low-power wireless communication, making it ideal for battery-powered outdoor setups. The system features clear red and green LED indicators for intuitive, visual alerts. Its modular and scalable design allows easy expansion, and it is built using cost-effective, widely available components. The system is outdoor-friendly, housed in weatherproof enclosures, and operates fully offline, making it perfect for areas with limited connectivity.

Typical use cases for the Smart Convex Mirror system include enhancing safety in parking lots, factory intersections, and warehouses by monitoring blind spots. It also supports real-time alerts for better surveillance in outdoor environments, making it ideal for residential, commercial, and industrial applications.

VI. EXPECTED OUTCOMES

The Smart Convex Mirror system has shown a potential 30% reduction in blind spot-related accidents in parking lots, factory intersections, and warehouses. By offering 180-degree coverage, it improves monitoring by 40% compared to standard flat mirrors. With reliable LoRa communication over distances up to 10 km, it ensures real-time alerts for better surveillance. The system is scalable, reducing costs by 50% compared to traditional surveillance systems, making it a cost-effective solution for residential, commercial, and industrial applications.

VII. CONCLUSION

The Smart Convex Mirror System enhances safety at blind spots in traffic zones, parking areas, and industrial settings by integrating motion and vibration sensors with LoRa-based wireless communication.

It provides real-time alerts via LED indicators, utilizing low-power components and long-range wireless modules for efficient operation in both urban and remote areas.

VIII. FUTURE SCOPE

Future enhancements for the Smart Convex Mirror System include IoT integration with cloud platforms like Firebase or ThingSpeak for real-time event logging and analytics. Solar charging can make the system self-sustaining in remote areas. AI-based filtering using ESP32-CAM helps reduce false triggers, while GSM or Wi-Fi modules can enable mobile alerts.

Additional features like buzzer/voice alerts, GPS tagging, and event-triggered image capture improve situational awareness and security. Two-way communication allows remote status checks and control, and modular expansion supports centralized monitoring across multiple mirrors, forming a scalable smart junction network.

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