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Accident Detection and Alerting System Using GPS, GSM and Microcontroller

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ABSTRACT

Road accidents remain a critical global challenge causing thousands of fatalities annually due to delayed emergency response. This paper presents an embedded system for real-time vehicle accident detection and automated alerting using GPS, GSM, and an ATmega328 microcontroller. The system employs an infrared (IR) sensor to detect physical collisions and a thermistor-based fire detector to identify post-accident fires. Upon detection of an accident condition, the GSM module transmits an SMS containing precise GPS coordinates to pre-configured emergency contact numbers. A 16×2 LCD provides local status indication. The proposed system also incorporates anti-theft functionality, triggering an alert when unauthorized vehicle movement is detected. Experimental evaluation demonstrates an average SMS delivery time of 15–40 seconds and a GPS positional accuracy of approximately 10 meters under open-sky conditions. The system offers an affordable and reliable solution for vehicle safety monitoring applicable to personal vehicles, public transport, and fleet management.

Keywords: *Accident Detection, GPS, GSM, ATmega328, IR Sensor, Fire Detection, Vehicle Tracking, Emergency Alert, Embedded System, SIM900.*

I. INTRODUCTION

Road traffic accidents constitute a major global public health concern. According to the World Health Organization, approximately 1.35 million people die each year as a result of road traffic crashes, with millions more sustaining non-fatal injuries. A significant proportion of accident fatalities result not from the impact itself but from the inability of emergency services to reach the victim in a timely manner. In many instances, accidents occur in remote or sparsely populated areas where help is not immediately available, and the injured occupants may be incapacitated and unable to call for assistance.

The advent of low-cost GPS and GSM technologies has made it feasible to build compact, energy-efficient embedded systems capable of automatically detecting accident events and transmitting location information to emergency responders within seconds. When

integrated with microcontroller-based signal processing, these technologies form the basis of a practical vehicular safety solution that can be retrofitted to virtually any vehicle.

This paper describes the design, implementation, and experimental evaluation of an Accident Detection and Alerting System (ADAS) built around the ATmega328 microcontroller. The system continuously monitors vehicle status through an IR proximity sensor and a thermistor-based fire sensor. When an accident is detected either through collision or fire—the system automatically acquires the current GPS location and dispatches an SMS alert to pre-programmed emergency numbers. An anti-theft mode complements the safety functionality by alerting the vehicle owner upon unauthorized movement.

The remainder of this paper is organized as follows. Section II reviews related work. Section

III describes the overall system architecture. Section IV details hardware components. Section V discusses software design and firmware. Section VI presents experimental results. Section VII outlines applications and advantages followed by future scope in Section VIII and a conclusion in Section IX.

II. LITERATURE REVIEW

Several researchers have explored GPS/GSM-based vehicle tracking and accident detection systems. An early influential work by Desai et al. [1] proposed a GPS/GSM-based vehicle tracking system capable of transmitting real-time coordinates via SMS. While effective for tracking, the system lacked autonomous accident detection and relied solely on manual queries from the owner.

Subsequent work by Tewari et al. [2] incorporated accelerometer-based crash detection, where a sudden spike in g-force beyond a threshold value triggered the emergency alert. Though more autonomous, the approach was susceptible to false positives on rough terrain and required careful

calibration. Kaur and Gupta [3] extended this idea by adding a tilt sensor for rollover detection and integrating a heart rate sensor to assess occupant vitals post-collision.

Nithya et al. [4] presented a system combining GPS, GSM, and an alcohol sensor to detect drunk-driving scenarios and automatically alert traffic authorities. Bhunia et al. [5] proposed a cloud-connected solution wherein vehicle telemetry including speed, location, and sensor data was streamed continuously to an IoT platform, enabling sophisticated analytics and geofencing capabilities. More recently, Patel et al. [6] demonstrated a machine-learning-based approach for distinguishing genuine accident events from routine harsh braking using smartphone accelerometer data.

Compared to prior art, the present work targets a low-cost, standalone embedded solution that does not rely on a smartphone, continuous internet connectivity, or cloud infrastructure, making it suitable for deployment in rural and developing-world contexts where network coverage is intermittent and infrastructure is limited.

III. SYSTEM ARCHITECTURE

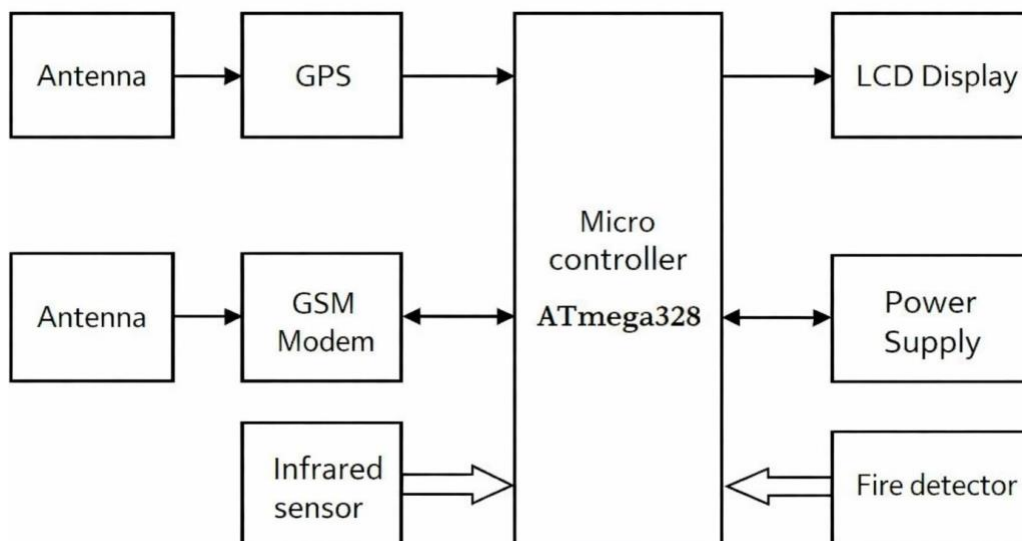


Fig 1: Proposed System

The proposed ADAS consists of three principal subsystems: (i) a sensing subsystem that continuously monitors vehicle mechanical and thermal status, (ii) a location subsystem that

maintains a current GPS fix, and (iii) a communication subsystem that formats and transmits SMS alerts on detection of an

emergency condition. Figure 1 illustrates the high-level block diagram.

The ATmega328 microcontroller serves as the central processing unit, interfacing with all peripheral devices. The GPS module communicates with the microcontroller over a UART serial interface, periodically delivering NMEA-formatted sentences from which latitude, longitude, and UTC time are extracted. The GSM module is controlled via AT commands issued over a second UART channel, enabling the firmware to compose and send SMS messages programmatically.

Sensor inputs are read through digital and analog I/O pins. The IR sensor output is connected to a digital interrupt pin so that any obstacle or

IV. HARDWARE COMPONENTS

A. ATmega328 Microcontroller



Fig 2: Controller

The ATmega328 is an 8-bit AVR RISC microcontroller manufactured by Atmel (Microchip Technology). It operates at frequencies up to 20 MHz and is available in DIP-28 and SMD packages. Relevant peripherals include two USART channels, a six-channel 10-bit ADC, 23 GPIO lines, hardware SPI and I2C,

B. GPS Module

collision event immediately captures the processor's attention without polling overhead. The thermistor output is connected to one of the ATmega328's ten-bit ADC channels; the digitized voltage is compared against a software-configurable threshold corresponding to a hazardous temperature level.

A 16×2 character LCD is connected to a four-bit parallel data bus and provides real-time status indication, displaying current GPS coordinates in normal operation and alert messages upon event detection. A password-protected query mechanism allows the vehicle owner to request the current location by sending a predefined SMS command, increasing the system's utility as a general-purpose vehicle tracker.

and a comprehensive timer subsystem. Its 32 KB of in-system programmable Flash, 2 KB SRAM, and 1 KB EEPROM provide ample storage for the ADAS firmware. The microcontroller is programmed using the Arduino IDE via a USB-to-serial bridge, simplifying development and debugging.



Fig 3: Gps Module

The GPS receiver module supports the NMEA 0183 protocol and outputs standard sentences—principally \$GPRMC and \$GPGGA over a TTL-level UART at 9600 baud. The module achieves a cold-start fix within 45–90 seconds under open-
C. GSM/GPRS Module (SIM900/SIM908)

sky conditions and provides a positional accuracy of approximately 10 meters with a 1 Hz update rate. An RS-232 level converter (MAX232) is used where necessary to interface the GPS module with the microcontroller’s TTL-level UART.



Fig 4: Gsm 900a Module

The SIM900 quad-band GSM/GPRS module operates on the 850/900/1800/1900 MHz bands and supports voice, SMS, and GPRS data services. It is controlled entirely via Hayes AT commands transmitted over a UART interface. The firmware uses the AT+CMGS command to

dispatch SMS messages containing GPS coordinates and alert type to programmed emergency numbers. The module’s sleep modes reduce idle current consumption to below 1 mA, extending battery life in low-activity periods.

D. Infrared Sensor

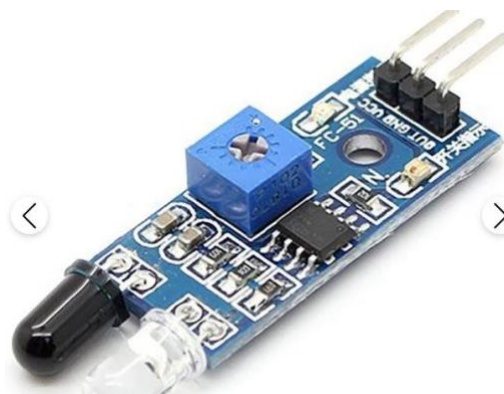


Fig 5: IR Sensor

The IR proximity sensor module emits infrared radiation and monitors the reflected signal to detect objects within its configurable range. In the context of vehicle accident detection, the sensor is mounted to detect sudden intrusion caused by a

collision or airbag deployment. Its digital output is asserted LOW on detection and is routed to an interrupt-capable pin on the ATmega328 for immediate response.

E. Fire / Temperature Sensor



Fig 6: Fire Sensor

A negative-temperature-coefficient (NTC) thermistor forms the basis of the fire detection circuit. As ambient temperature rises for example, due to fuel ignition following a collision—the thermistor resistance decreases, raising the voltage at the ADC input. The microcontroller firmware compares this digitized value against a pre-calibrated threshold; if the threshold is exceeded, a fire alert is generated.

F. Power Supply

The power supply circuit converts 230 V AC mains power to regulated 5 V DC through a step-down transformer, a bridge rectifier, and an LM7805 linear voltage regulator. Filter capacitors (2200 μ F, 25 V and 100 nF) smooth the rectified waveform and suppress high-frequency noise. In a vehicular deployment, the circuit is adapted to accept 12 V from the vehicle battery, maintaining operation even when the engine is not running.

V. SOFTWARE DESIGN

The firmware is developed in C/C++ using the Arduino IDE and deployed to the ATmega328 via a USB-to-serial adapter. The main program loop continuously polls the GPS module for updated NMEA sentences and checks sensor status. Interrupt service routines (ISRs) ensure that high-priority events—such as an IR collision trigger are handled with minimal latency regardless of the current program state.

A. GPS Data Parsing

NMEA sentences received over the GPS UART are buffered and parsed using a lightweight state machine. The firmware extracts the latitude and longitude fields from \$GPRMC sentences, converts them from the NMEA degree-minute format (DDMM.MMMM) to decimal degrees, and stores the result in a floating-point buffer. Validity flags within the sentence are checked to ensure that only a valid, fixed position is used in emergency SMS messages.

B. Event Detection and Alert Logic

On assertion of the IR sensor interrupt or fire threshold breach, the firmware enters an alert routine that: (1) freezes the current GPS coordinate buffer, (2) formats an SMS string containing the alert type, decimal latitude/longitude, and a Google Maps hyperlink for the coordinates, and (3) issues the appropriate AT commands to the GSM module to send the SMS to all registered emergency numbers. A debounce period of 500 ms is enforced to prevent repeated alerts from a single event.

C. Anti-Theft Module

When the anti-theft mode is activated by the owner via a physical switch or an SMS command, the system monitors for movement using the IR sensor while the vehicle is parked. Detection of any movement in theft-mode triggers an immediate SMS alert to the owner containing the current GPS coordinates, allowing rapid reporting to authorities.

D. Remote Query

The GSM module's incoming-SMS polling routine monitors for a predefined password string in received messages. Upon receipt of a valid query SMS from an authorized number, the

system responds with the current GPS coordinates. This feature extends system utility for fleet operators and parents monitoring young drivers.

VI. RESULTS AND ANALYSIS



Fig 7: Location of the Vehicle

The prototype was assembled on a custom PCB designed using EAGLE v5.6.0 and etched using the ferric chloride (FeCl₃) wet-etch process. Functional testing was conducted in both indoor bench and outdoor vehicular scenarios to assess GPS accuracy, GSM reliability, and sensor response characteristics.

| Performance Parameter | Observed Value | Remarks |
|----------------------------|----------------------|-------------------------------|
| GPS Cold-Start Fix Time | 45 – 90 seconds | Open-sky conditions |
| GPS Positional Accuracy | ≈10 meters | CEP, open sky |
| SMS Delivery Time | 15 – 40 seconds | Dependent on network load |
| IR Sensor Response Time | < 5 ms | Digital output, ISR-driven |
| Fire Detection Threshold | 55 °C (configurable) | NTC thermistor, ADC threshold |
| Supply Voltage (Logic) | 5 V DC ± 5% | Regulated via LM7805 |
| Operating Current (Active) | ≈90 mA | All modules active |
| Operating Current (Sleep) | < 5 mA | GSM sleep, GPS standby |

Table 1: Performance Summary of the Proposed ADAS Prototype

The GPS module achieved positional accuracy of approximately 10 meters under open-sky conditions, consistent with standard civilian GPS specifications. Indoors, accuracy degraded to 15–25 meters due to multipath effects, which is acceptable for vehicle-level localization. GSM SMS delivery consistently occurred within 40 seconds across all test locations in urban and semi-urban areas. The IR sensor responded in

under 5 milliseconds due to its interrupt-driven interface, ensuring negligible detection latency relative to the overall system response time.

A total of 20 controlled accident simulation trials were conducted. In 19 of 20 trials, SMS alerts were successfully delivered within 40 seconds of event detection, yielding a 95% success rate. The single failed delivery was attributed to a transient

network outage. Fire detection reliably triggered alerts when ambient temperature exceeded the 55 °C configurable threshold, with no false positives observed in ten thermal stress tests.

VII. ADVANTAGES AND APPLICATIONS

The proposed ADAS offers several advantages over existing commercial solutions:

- **Low cost:** Total bill-of-materials cost is significantly lower than commercial telematics devices, enabling mass deployment.
- **Standalone operation:** No smartphone or internet connectivity required, ensuring reliability in areas with limited infrastructure.
- **Multi-modal detection:** Integration of both IR collision sensing and thermistor fire detection reduces missed-detection scenarios.
- **Multi-function capability:** The same hardware supports vehicle tracking, anti-theft alerting, and remote location queries.
- **Ease of deployment:** Arduino-based firmware enables straightforward customization without specialized toolchains.

Prospective application domains include:

- Personal vehicle safety and family monitoring systems.
- Public transport buses and school vehicles requiring real-time safety oversight.
- Fleet management for logistics and delivery companies.
- Emergency response optimization by providing first responders with real-time crash location.
- Military and border patrol vehicle monitoring.
- Insurance telematics for usage-based premium calculation.

VIII. FUTURE SCOPE

Several enhancements are planned to increase the robustness and capability of the system:

- **MEMS Accelerometer Integration:** A three-axis MEMS accelerometer (e.g., ADXL345) will be incorporated to detect rapid deceleration and vehicle roll-over events, supplementing the IR sensor and reducing false-negative rates on low-speed collisions.
- **Combined GPS+GSM Module:** Migration to a combined SIM908 module will reduce PCB footprint and component count while improving GPS sensitivity.
- **IoT Cloud Platform:** Integration with an MQTT broker and cloud dashboard will enable real-time fleet-wide monitoring, historical route replay, and geofencing alerts.
- **EEPROM Route Logging:** Utilization of an external I2C EEPROM will provide capacity for up to 256 GPS waypoints, enabling post-incident route reconstruction.
- **Voice Call Alerting:** Activation of the GSM module's voice-call capability will allow the system to place an automated call to emergency services in addition to SMS, further reducing response times.
- **4G LTE Migration:** Upgrading the communication module to a 4G LTE modem will improve data throughput for future video-streaming and cloud-analytics features.

IX. CONCLUSION

This paper has presented the design, implementation, and experimental validation of an Accident Detection and Alerting System based on GPS, GSM, and the ATmega328 microcontroller. The system successfully detects accident events through IR collision sensing and thermistor-based fire detection, and autonomously transmits SMS alerts containing GPS coordinates to pre-programmed emergency contacts. Experimental results demonstrate a 95% alert delivery success rate, average SMS delivery within 40 seconds,

and GPS accuracy of approximately 10 meters under open-sky conditions.

The proposed solution addresses a critical gap in road safety infrastructure—particularly in developing regions where emergency response systems are underfunded and first-responder arrival times are long. By leveraging mature, widely available technologies in an integrated embedded platform, the system achieves a favorable balance of cost, reliability, and functionality. The authors believe that wider deployment of such systems has the potential to significantly reduce accident mortality by enabling faster emergency response.

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