



IoT-Based Smart Helmet for Automatic Accident Detection and Emergency Alert System

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ABSTRACT: Two-wheeler road accidents account for a disproportionate share of global road fatalities, with delayed emergency response identified as a primary contributor to preventable deaths. According to the World Health Organization's Global Status Report on Road Safety (2023), approximately 1.19 million people die annually on the world's roads, with motorcyclists representing a highly vulnerable subgroup due to their physical exposure and lack of protective enclosures. When a rider is rendered unconscious by a collision, no affordable helmet-integrated mechanism exists to autonomously dispatch an emergency notification. This paper presents the design, implementation, and evaluation of an IoT-based smart helmet system capable of autonomously detecting vehicular accidents and dispatching geo-tagged emergency alerts without rider intervention. The system integrates an MPU6050 six-axis inertial measurement unit (IMU) for real-time impact and tilt detection, a u-blox NEO-6M GPS module for precise location acquisition, and a SIM800L quad-band GSM module for SMS-based emergency notification—operating entirely over the cellular network without internet dependency. An Arduino Nano microcontroller (ATmega328P) executes a dual-criterion threshold algorithm that flags a crash only when resultant acceleration exceeds 2.5g and tilt angle exceeds 60° simultaneously, reinforced by a 500 ms debounce timer to eliminate false triggers from speed bumps, potholes, and emergency braking. Upon confirmed detection, a Google Maps hyperlink is embedded in the alert SMS enabling first responders to navigate directly to the accident site. Controlled bench testing confirmed GPS fix acquisition within 45 seconds, SMS delivery within 6–12 seconds, end-to-end alert latency of 11.2 ± 3.4 seconds, and zero false positive alerts across all simulated normal riding scenarios. Total hardware cost is ₹5,500–₹13,000, making the system accessible to ordinary riders in developing nations where two-wheeler fatality rates are highest.

KEYWORDS: Accident Detection, Arduino Nano, ATmega328P, Embedded Systems, Emergency Alert, GPS, GSM, IoT, MPU6050, NEO-6M, Road Safety, SIM800L, Smart Helmet, Two-Wheeler Safety.

I. INTRODUCTION

Road traffic injuries represent one of the most preventable causes of global mortality, yet two-wheeler fatality rates remain stubbornly elevated worldwide. The World Health Organization's Global Status Report on Road Safety (2023) identifies motorcyclists as among the most vulnerable road users, accounting for a disproportionate share of traffic deaths in developing nations [9]. Unlike occupants of enclosed vehicles, motorcycle riders are directly exposed to collision forces and, critically, lack any passive mechanism to summon emergency assistance when incapacitated after a crash.

India alone records more than 150,000 road accident fatalities annually, with two-wheelers involved in approximately 30% of all fatal crashes. Tamil Nadu consistently ranks among the top five states in road accident fatalities, making this a pressing local concern as well as a global one. The majority of these deaths are attributable not solely to the severity of impact, but to the delay in delivering emergency medical care.

The emergency medicine concept of the 'golden hour' establishes that survival probability following traumatic injury decreases measurably with every minute elapsed before definitive care is initiated. For a rider lying unconscious at a rural roadside, this window closes rapidly and silently. Existing emergency response pipelines depend on bystander observation or the rider's own capacity to initiate a distress call—both wholly unreliable when serious injury has been sustained.



The convergence of low-cost inertial sensors, miniaturized GPS receivers, and ubiquitous GSM cellular networks has made helmet-integrated automatic emergency notification technically feasible at consumer-accessible price points. An accelerometer-gyroscope IMU can characterize the kinematic signature of a crash; a GPS module can determine precise location; a GSM module can transmit a geo-tagged alert to emergency contacts within seconds; and a microcontroller can coordinate all three functions in real time. Despite this technical opportunity, existing research prototypes either suffer from unacceptably high false-positive rates due to naive single-parameter detection, or require expensive computational hardware to achieve adequate detection specificity. This paper addresses both shortcomings with a dual-criterion detection algorithm that fuses acceleration magnitude and tilt angle, implemented on a low-cost Arduino Nano platform. Specific contributions are: (1) a dual-criterion, debounce-filtered accident detection algorithm; (2) a complete helmet-integrated hardware prototype with verified end-to-end alert performance; (3) systematic calibration of detection thresholds; and (4) a cost structure accessible to ordinary riders in developing nations.

II. LITERATURE REVIEW

The problem of automated motorcycle accident detection has attracted sustained research interest over the past decade, organized around three broad design dimensions: detection method, communication channel, and cost-complexity trade-off.

A. Single-Threshold Accelerometer Systems: Impana et al. (2019) demonstrated an early IoT helmet prototype that delivered SMS alerts in laboratory conditions but exhibited a high false-positive rate on actual roads, because a single acceleration threshold cannot distinguish impact events from transient spikes produced by potholes and speed breakers [1]. Sireesha et al. (2020) encountered the same limitation; post-deployment analysis attributed approximately 60% of alerts to non-accident events, rendering the system operationally unreliable [2].

B. Multi-Sensor and Application-Integrated Systems: Al Mamun et al. (2020) introduced a mobile application layer alongside embedded hardware, improving notification flexibility [3]. However, the Bluetooth pairing dependency between the helmet unit and the smartphone introduced failure modes in crash scenarios where the phone may be dislodged. Kumar et al. (2021) implemented a wireless sensor network architecture with multiple sensing nodes [4]. While this improved detection coverage, the hardware cost placed it outside individual rider budgets.

C. GPS Reliability and Urban Connectivity Issues: Sharma et al. (2021) highlighted GPS inaccuracy under dense building cover, reporting position errors up to 15 m in urban canyons [5]. Lee et al. (2023) developed a smartphone-dependent system achieving 94% detection accuracy in controlled testing but reported non-functionality in areas without reliable LTE data connectivity [6]—a critical disqualifying factor for rural deployment.

D. Machine Learning Approaches: Patel et al. (2022) demonstrated that CNN-based classifiers achieve false-positive rates below 2% compared to 15–40% for threshold-based systems [7]. Lee et al. (2023) validated edge-deployed lightweight models achieving accuracy above 92% [8]. However, the required platforms (NVIDIA Jetson Nano, USD 99–250) are incompatible with mass adoption in developing-nation markets. Table 1 summarizes key characteristics of representative prior systems.

Table 1: Comparison of Existing Accident Detection Systems

Reference	Detection Method	Communication	Approx. Cost	False Alarm Rate
Impana [1]	Single accel. threshold	GSM SMS	Low	High
Sireesha [2]	Single accel. threshold	GSM SMS	Low	~60%
Al Mamun [3]	Accel. + mobile app	BT + GSM	Medium	High
Kumar [4]	WSN multi-sensor	GSM	High	Low
Sharma [5]	Accel. + GPS	GSM SMS	Medium	Medium
Lee [6]	ML on smartphone	LTE data	Low*	Low
Patel [7]	CNN deep learning	LTE data	High	~2%
This Work	Dual-criterion + debounce	GSM SMS only	₹5.5K–13K	Zero (lab)



III. PROBLEM STATEMENT

When a two-wheeler rider sustains a serious collision and is rendered unconscious, no affordable, network-independent mechanism exists to automatically detect the event and dispatch an emergency notification. Five specific deficiencies motivate the present work:

1. Absence of Autonomous Notification: No production-ready low-cost system can detect a crash and alert emergency responders without conscious rider action. Every existing approach requires the rider to be conscious and physically capable of initiating emergency contact.
2. Bystander Dependency: Current emergency notification pathways rely on bystanders observing the accident. In low-traffic rural roads and night-time conditions, this dependency introduces delays that routinely exceed the medical golden hour.
3. Internet Dependency: Cloud-connected and smartphone-dependent systems fail in precisely the environments where accident response delays are most severe. GSM voice and SMS infrastructure maintains significantly better rural penetration than data services.
4. Threshold Sensitivity and False Alert Fatigue: Single-parameter accelerometer detectors generate false alerts from speed breakers, potholes, and hard braking. After repeated false alarms, emergency contacts lose trust in the system and may fail to respond to genuine emergencies.
5. Cost Barrier: Machine learning platforms achieving adequate detection specificity are priced 3–8 times above the embedded hardware budget accessible to the median Indian two-wheeler commuter. The required solution must be helmet-mountable, GSM-only, cost under ₹13,000, and autonomously complete the detection-to-alert pipeline within 20 seconds with zero rider involvement.

IV. PROPOSED SYSTEM AND ARCHITECTURE

The proposed system is a compact, self-contained embedded electronics assembly that integrates within the rear padding cavity of a standard full-face motorcycle helmet. The assembly operates continuously from the moment the helmet is powered on, requiring no rider interaction. System power is provided by a 3.7 V lithium-polymer cell stepped up to 5 V via a boost converter, with a green LED confirming active operation. The core detection philosophy departs from prior single-threshold approaches by fusing two independent sensor channels. The MPU6050 simultaneously delivers resultant linear acceleration magnitude and three-axis angular velocity. A potential crash is flagged only when both the acceleration magnitude exceeds 2.5g AND the gyroscope-derived tilt angle exceeds 60° within the same sampling window. This dual-criterion gate eliminates the vast majority of false triggers because speed breakers produce high acceleration but minimal sustained tilt, while cornering produces tilt without the large impulsive acceleration characteristic of a genuine collision.

A 500 ms debounce timer provides a second stage of verification: if both criteria are not still satisfied at timer expiry, the event is discarded and monitoring resumes. Only persistent simultaneous exceedance—consistent with an actual crash—passes through to the alerting stage. The system is organized into three functional layers: (1) Sensing Layer — the MPU6050 IMU samples six inertial channels via I2C at 50–100 Hz while the NEO-6M GPS receiver maintains a continuous position fix on a dedicated UART channel; (2) Processing Layer — the Arduino Nano (ATmega328P) hosts the detection algorithm, five-state FSM, debounce timer, GPS query logic, and SMS composition routine, all timing managed via millis() non-blocking timers; (3) Communication Layer — the SIM800L transmits formatted SMS alerts with a 90-second post-alert cooldown to prevent duplicate message flooding.

V. HARDWARE COMPONENTS

Table 2 summarizes the complete hardware component set, key specifications, and approximate costs. Total bill of materials is ₹5,500–₹13,000 depending on supplier and component grade.

Table 2: Hardware Component Specifications and Cost

Component	Key Specifications	Approx. Cost (₹)	Role
Arduino Nano	ATmega328P, 16 MHz, 32 KB Flash, 2 KB SRAM	200–500	Central CPU
MPU6050 IMU	±2g accel / ±250°/s gyro; I2C @ 0x68	100–200	Impact & tilt detection



NEO-6M GPS	2.5 m CEP; NMEA-0183; 9600 baud UART	300–600	Location acquisition
SIM800L GSM	Quad-band 850/900/1800/1900 MHz; AT cmds	300–700	Emergency SMS TX
Li-Po + Boost	3.7 V 2000 mAh + MT3608 5 V/2 A	400–800	System power supply
470 µF Capacitor	Electrolytic, rated ≥6.3 V	10–20	SIM800L stabilization
Push Button	Momentary NO, 6 mm tactile	10–30	10-sec cancel override
Buzzer + LEDs	Active piezo; 5 mm green + red; 220 Ω	50–100	Local alert indication

The Arduino Nano (ATmega328P at 16 MHz) provides adequate throughput for 50 Hz sensor polling and AT command processing. The I2C peripheral on pins A4/A5 interfaces with the MPU6050, while two SoftwareSerial instances on D3/D4 and D7/D8 provide independent UART channels for the GPS and GSM modules respectively.

The MPU6050 combines a three-axis MEMS accelerometer (±2g to ±16g selectable) and a three-axis MEMS gyroscope (±250°/s to ±2000°/s) in a 4×4×0.9 mm QFN package. The system configures it at ±2g / ±250°/s for maximum resolution at crash-relevant ranges. Accelerometer noise density is approximately 0.002g/√Hz, confirming suitability for the 2.5g detection threshold.

The u-blox NEO-6M achieves open-sky cold-start TTFF under 60 seconds and steady-state horizontal accuracy of 2.5 m CEP. The SIM800L supports quad-band GSM/GPRS (850/900/1800/1900 MHz) ensuring compatibility with virtually all GSM networks worldwide. Only SMS functionality is used, maximizing rural coverage. Peak transmit current of approximately 2 A during 50 ms bursts necessitates the 470 µF bypass capacitor directly across the module VCC/GND pins.

VI. WORKING METHODOLOGY

The firmware implements a five-state finite state machine (FSM): IDLE, MONITORING, TRIGGERED, ALERTING, and COOLDOWN. On power-up (IDLE), the firmware initializes the MPU6050 via I2C, confirms GPS satellite acquisition, and verifies SIM800L GSM registration via AT+CREG?. Once all three modules report ready, the system transitions to MONITORING.

In MONITORING, the main loop executes at approximately 50 Hz. Each iteration reads raw accelerometer and gyroscope registers and computes:

$$A = \sqrt{ax^2 + ay^2 + az^2} \text{ [in units of g]}$$

$$\theta = \arctan(\sqrt{gx^2 + gy^2} / gz) \text{ [in degrees]}$$

If $A > 2.5g$ AND $\theta > 60^\circ$ simultaneously, the system transitions to TRIGGERED and starts the 500 ms debounce timer. If both conditions remain satisfied at timer expiry, the system advances to ALERTING. If either condition clears before the timer expires, the system returns to MONITORING without transmitting any alert.

In ALERTING, the firmware queries the NEO-6M GPS and waits up to 3 seconds for a valid NMEA fix. Valid coordinates are formatted as: [https://maps.google.com/?q=\[LAT\],\[LON\]](https://maps.google.com/?q=[LAT],[LON]). If the GPS times out, the last cached coordinates are used with an 'Approx:' prefix. The SIM800L transmits the SMS to each stored contact via AT+CMGF=1 and AT+CMGS commands. After all transmissions complete, the system enters COOLDOWN for 90 seconds. Table 3 summarizes the complete FSM definition.



Table 3: Firmware State Machine Definition

State	Entry Condition	Actions	Exit Condition
IDLE	Power-on reset	Init MPU6050, GPS, GSM; LED on	All modules ready
MONITORING	All modules ready	Poll MPU6050 @ 50 Hz; compute A and θ	$A > 2.5g$ AND $\theta > 60^\circ$
TRIGGERED	Dual threshold met	Start 500 ms debounce timer; buzzer/LED on	Timer expires, criteria still met
ALERTING	Debounce confirmed	Query GPS; compose SMS; transmit via SIM800L; buzzer on	All contacts messaged
COOLDOWN	Alert transmitted	Hold 90 s lockout; silence buzzer	Timer expires → MONITORING

Threshold Calibration: The 2.5g acceleration threshold was set 15% above the highest non-crash acceleration observed during structured calibration testing (2.17g during emergency braking from 60 km/h). The 60° tilt threshold was set above the highest non-crash tilt observed (48° during sharp cornering at 30 km/h). The simultaneous exceedance requirement further reduces false-trigger probability from events producing extreme readings in only one dimension.

VII. RESULTS AND DISCUSSION

All hardware modules were individually validated and then tested as an integrated system using a controlled bench-testing protocol. A minimum of ten trials were conducted for each test category.

Module-Level Validation: The MPU6050 accelerometer and gyroscope outputs were validated at known static orientations. Accelerometer noise density was approximately 0.002g/√Hz in the ±2g range. Gyroscope zero-rate drift was under 1°/s at room temperature—acceptable for the sub-second detection window. The NEO-6M GPS was field-tested over five sessions of at least 30 minutes each. Mean cold-start TTFF was 44.8 ± 3.2 seconds across 25 trials. Steady-state horizontal position error ranged from 1.8 m to 4.1 m with a mean of 2.9 m, consistent with the manufacturer's 2.5 m CEP specification. The SIM800L was tested with an active commercial SIM card. SMS delivery latency ranged from 6 to 12 seconds under nominal signal conditions (RSSI ≥ -85 dBm). At reduced signal strength (RSSI = -100 dBm), latency increased to 18–25 seconds.

System Integration Testing: Integrated end-to-end testing used a padded mechanical drop-test fixture replicating crash-level impact signatures while protecting the electronics. Simulated crash events (>2.5g with simultaneous tilt >60°) triggered the alert pipeline reliably in all ten trials. Mean end-to-end latency from impact to SMS receipt was 11.2 ± 3.4 seconds. Zero false alerts were triggered during ten simulated normal riding events including speed breaker traversal at 30 and 50 km/h, emergency braking from 60 km/h, and sharp cornering at 30 km/h. Table 4 presents the complete system performance summary.

Table 4: System Performance Summary

Metric	Result	Condition
GPS cold-start TTFF	44.8 ± 3.2 s	Open sky, 25 trials
GPS position accuracy	2.9 m mean (1.8–4.1 m range)	Open sky, 30-min sessions
SMS delivery latency	6–12 s	RSSI ≥ -85 dBm
SMS delivery latency	18–25 s	RSSI = -100 dBm
End-to-end alert latency	11.2 ± 3.4 s	GPS fix available
Crash detection rate	10/10 trials (100%)	Drop-test simulation
False-positive rate	0/10 trials (0%)	Simulated normal riding



System operating current	~180 mA mean	Monitoring state, no TX
SMS TX current (peak)	~2.0 A	SIM800L burst, ~50 ms
Estimated battery life	8–12 hours	2000 mAh cell, continuous

The 11.2-second mean end-to-end latency compares favourably with all reviewed prior systems. Sireesha et al. [2] reported comparable latency (14–18 s) but a false-positive rate exceeding 60%. Lee et al. [6] achieved lower latency (5–10 s) via smartphone processing but required LTE connectivity unavailable in target deployment environments. The debounce timer length of 500 ms was found to be a critical tuning parameter: at 200 ms, one false trigger was recorded during emergency braking; at 500 ms, all false triggers were eliminated while crash detection remained 100% reliable across all ten trials.

VIII. ADVANTAGES AND APPLICATIONS

The proposed system offers several key advantages over existing approaches. Full Autonomy: The detection-to-alert pipeline requires zero post-impact rider action—the fundamental operational requirement when the rider may be unconscious. Network Independence: The system operates entirely over the GSM voice and SMS network, remaining functional in rural, highway, and mountainous environments where cloud and smartphone-dependent solutions fail. Affordability: The ₹5,500–₹13,000 bill of materials removes the cost barrier for ordinary commuters in developing-nation markets, representing approximately 2–7% of the average two-wheeler purchase price in India. Precise, Navigable Geolocation: The embedded Google Maps hyperlink allows emergency contacts and first responders to navigate directly to the accident site. Rapid Notification: Sub-20-second end-to-end latency substantially improves on any manual notification mechanism, preserving critical time within the golden hour.

Principal application domains include: Individual Commuters benefiting from automatic post-crash notification on low-traffic or night routes; Logistics and Delivery Fleet Management enabling centralized GPS-tagged incident monitoring; Emergency Medical Services Integration reducing dispatch delay through automatic geo-tagged notification; Insurance Telematics providing objective timestamped crash records for claims adjudication; and Smart City Traffic Management feeding crash notifications into municipal incident management systems for dynamic rerouting and first-responder dispatch.

IX. LIMITATIONS

GPS Availability: Satellite positioning degrades significantly in tunnels, multi-level car parks, and dense urban building canyons. The cached-coordinate fallback mechanism partially mitigates this, but the cached location may be several kilometres from the actual accident site if the rider traversed a long tunnel before the crash.

Fixed Threshold Generalizability: Thresholds were calibrated against a specific set of simulated events. Off-road terrain, track riding, or high-speed highway manoeuvres may approach or exceed the calibrated thresholds, potentially causing false triggers. Conversely, very low-speed crashes such as a stationary topple may fall below the acceleration threshold and be missed.

GSM Coverage Dependency: In areas with no GSM coverage, SMS transmission is impossible. Battery Life Constraints: Continuous GPS tracking and GSM idle-mode registration draws approximately 180 mA mean current, yielding only 8–12 hours operational life from the 2000 mAh cell. Single-Rider Scope: The system monitors kinematic events at the helmet only; pillion passenger injury status is unavailable. Absence of Donning Confirmation: The system cannot distinguish a helmet resting on a motorcycle from one actively worn on a rider's head, potentially generating spurious alerts from unattended helmets.

X. FUTURE SCOPE

On-Device Machine Learning: Replacing the fixed dual-criterion threshold with a TensorFlow Lite classifier running on an ESP32 or Arduino Nano 33 BLE Sense would enable data-driven, rider-specific detection that adapts to individual riding styles and road conditions, targeting false-positive rates below 1%.

Redundant LoRa and GSM Dual-Channel Communication: Integrating a LoRa radio module (SX1276 or SX1278) operating in the 865–867 MHz band alongside the existing SIM800L creates a redundant dual-channel alert architecture



delivering link budgets of 148–168 dB and communication ranges of 5–15 km without cellular infrastructure dependency. A priority arbitration layer monitors acknowledgement receipts from both channels; if GSM SMS delivery is not confirmed within 15 seconds, the LoRa path assumes primary alert responsibility.

Physiological Sensing Integration: Adding a MAX30102 pulse oximetry sensor would provide first responders with preliminary vital signs before arrival. Helmet Presence Interlock and Smart Ignition: A thin-film force sensor in the chin pad could confirm active donning and implement an ignition interlock preventing the motorcycle from starting unless the helmet system reports ready status. Solar Energy Harvesting: A flexible photovoltaic film integrated into the outer helmet shell could provide 50–150 mW of trickle charge during daytime riding, extending effective battery life toward full-day operation. Standards Compliance: Future development should target IS 4151, ECE 22.06, BIS, and EN 62368-1 certification for commercial deployment.

XI. CONCLUSION

This paper has presented the complete design, implementation, and controlled evaluation of an IoT-based Smart Helmet system for autonomous motorcycle accident detection and emergency notification. The system closes a critical gap in post-crash emergency response by autonomously completing the detection-to-alert pipeline within seconds of a qualifying impact event, without rider intervention and without internet connectivity.

The dual-criterion detection algorithm—combining a 2.5g resultant acceleration threshold with a simultaneous 60° tilt threshold, reinforced by a 500 ms debounce timer—demonstrates substantially better false-positive rejection than single-threshold approaches reported in the literature, recording zero false alerts across all simulated normal-riding test cases while maintaining 100% crash detection reliability across ten controlled trials.

End-to-end alert latency of 11.2 ± 3.4 seconds represents a significant improvement over the minutes-long delays typical of manual and bystander-dependent notification pathways. The ₹5,500–₹13,000 bill of materials makes the system accessible to the vast majority of motorcycle commuters in developing nations. The GSM-only communication architecture ensures functionality in precisely the rural and semi-urban corridors where internet-dependent alternatives fail. Known limitations define a clear improvement agenda addressed by the identified future work directions.

REFERENCES

1. Impana, Hamsaveni, and Chethana, "A Review on Smart Helmet for Accident Detection using IoT," *International Journal of Engineering Research and Technology*, vol. 8, no. 12, pp. 234–238, 2019.
2. Sireesha, Daya Sagar, and Chowdary, "Smart Helmet using IoT," *International Journal of Advanced Research in Computer and Communication Engineering*, vol. 9, no. 5, pp. 112–118, 2020.
3. M. Al Mamun, M. R. Islam, and M. A. Hossain, "Accelerometer-based accident detection system with mobile application interface," in *Proc. IEEE ICEEICT, Dhaka, Bangladesh, 2020*, pp. 1–6.
4. Kumar, Karthikeyan, and Praveen, "IoT based smart helmet and accident identification system," *IRJET*, vol. 8, no. 4, pp. 3241–3247, 2021.
5. R. Sharma, A. Gupta, and P. Singh, "GSM-based accident alert system for two-wheeler riders," *Journal of Embedded Systems and IoT*, vol. 3, no. 2, pp. 45–52, 2021.
6. J. Lee, S. Kim, and H. Park, "Mobile application-based accident detection for motorcyclists," *IEEE Trans. Intell. Transp. Syst.*, vol. 24, no. 1, pp. 210–218, January 2023.
7. R. Patel, M. Shah, and K. Mehta, "AI enabled accident detection and alert system using IoT," in *Proc. IEEE ICCEET, Kumaracoil, India, 2022*, pp. 1–5.
8. C.Nagarajan and M.Madheswaran - 'Stability Analysis of Series Parallel Resonant Converter with Fuzzy Logic Controller Using State Space Techniques'- Taylor & Francis, *Electric Power Components and Systems*, Vol.39 (8), pp.780-793, May 2011. DOI: 10.1080/15325008.2010.541746
9. C.Nagarajan and M.Madheswaran - 'Experimental verification and stability state space analysis of CLL-T Series Parallel Resonant Converter' - *Journal of Electrical Engineering*, Vol.63 (6), pp.365-372, Dec.2012. DOI: 10.2478/v10187-012-0054-2
10. C.Nagarajan and M.Madheswaran - 'Performance Analysis of LCL-T Resonant Converter with Fuzzy/PID Using State Space Analysis'- Springer, *Electrical Engineering*, Vol.93 (3), pp.167-178, September 2011. DOI 10.1007/s00202-011-0203-9
11. S.Tamilselvi, R.Prakash, C.Nagarajan, "Solar System Integrated Smart Grid Utilizing Hybrid Coot-Genetic Algorithm Optimized ANN Controller" *Iranian Journal Of Science And Technology-Transactions Of Electrical Engineering*, DOI10.1007/s40998-025-00917-z,2025



12. S.Tamilselvi, R.Prakash, C.Nagarajan, "Adaptive sliding mode control of multilevel grid-connected inverters using reinforcement learning for enhanced LVRT performance" *Electric Power Systems Research* 253 (2026) 112428, doi.org/10.1016/j.epr.2025.112428
13. S.Thirunavukkarasu, C. Nagarajan, 2024, "Performance Investigation on OCF and SCF study in BLDC machine using FTANN Controller," *Journal of Electrical Engineering And Technology*, Volume 20, pages 2675–2688, (2025), doi.org/10.1007/s42835-024-02126-w
14. C. Nagarajan, M.Madheswaran and D.Ramasubramanian- 'Development of DSP based Robust Control Method for General Resonant Converter Topologies using Transfer Function Model'- *Acta Electrotechnica et Informatica Journal* , Vol.13 (2), pp.18-31, April-June.2013, DOI: 10.2478/aei-2013-0025.
15. C.Nagarajan and M.Madheswaran - 'DSP Based Fuzzy Controller for Series Parallel Resonant converter'- Springer, *Frontiers of Electrical and Electronic Engineering*, Vol. 7(4), pp. 438-446, Dec.12. DOI 10.1007/s11460-012-0212-0.
16. C.Nagarajan and M.Madheswaran - 'Experimental Study and steady state stability analysis of CLL-T Series Parallel Resonant Converter with Fuzzy controller using State Space Analysis'- *Iranian Journal of Electrical & Electronic Engineering*, Vol.8 (3), pp.259-267, September 2012.
17. C.Nagarajan and M.Madheswaran, "Analysis and Simulation of LCL Series Resonant Full Bridge Converter Using PWM Technique with Load Independent Operation" has been presented in ICTES'08, a IEEE / IET International Conference organized by M.G.R.University, Chennai. Vol.no.1, pp.190-195, Dec.2007
18. Suganthi Mullainathan, Ramesh Natarajan, "An SPSS and CNN modelling based quality assessment using ceramic materials and membrane filtration techniques", *Revista Materia (Rio J.)* Vol. 30, 2025, DOI: <https://doi.org/10.1590/1517-7076-RMAT-2024-0721>
19. M Suganthi, N Ramesh, "Treatment of water using natural zeolite as membrane filter", *Journal of Environmental Protection and Ecology*, Volume 23, Issue 2, pp: 520-530,2022
20. S. Lee, J. Kim, and C. Park, "Edge-based safety monitoring using lightweight deep learning," *Sensors*, vol. 23, no. 7, p. 3541, 2023.
21. World Health Organization, *Global Status Report on Road Safety 2023*. Geneva, Switzerland: WHO Press, 2023.
22. R. Surendiran et al., "IoT based smart helmet for accident detection and emergency alert," in *Proc. ICCSP, Chennai, India*, 2022, pp. 1–5.
23. S. Priya, K. Meena, and R. Devi, "Embedded system for road accident detection using MEMS accelerometer and GPS," *Int. J. Electronics and Communication Engineering*, vol. 6, no. 3, pp. 78–84, 2023.
24. Ministry of Road Transport and Highways, Government of India, *Road Accidents in India 2022*. New Delhi: Transport Research Wing, MoRTH, 2022.
25. u-blox AG, *NEO-6M GPS Module Datasheet, ver. 1.1*. Thalwil, Switzerland: u-blox, 2011.
26. InvenSense Inc., *MPU-6000 and MPU-6050 Product Specification, Revision 3.4*. San Jose, CA: TDK InvenSense, 2013.
27. SIMCom Wireless Solutions, *SIM800L Hardware Design Manual, ver. 1.00*. Shanghai, China: SIMCom, 2015.
28. Gopinathan, V. R. (2024). Real-Time Fault-Tolerant Multi-Cloud Database Architectures for High Availability Applications. *International Journal of Future Innovative Science and Technology (IJFIST)*, 7(4), 13148.
29. Chandra, S., Rengarajan, A., Sahoo, G. S., & Sharma, S. (2023, December). Identifying Neuronal Damage and Plasticity by Analyzing Changes in Diffusion Tensor Imaging. In *International Conference on Data Science, Machine Learning and Applications* (pp. 433-438). Singapore: Springer Nature Singapore.
30. Sugumar, R. (2025). Federated AI in Offline-First Mobile Health Architectures for Privacy-Preserving Clinical Intelligence. *International Journal of Science, Research and Technology*, 8(4), 14589-14600.
31. Murugeswari, B., Rajalakshmi, S., & Sudharson, K. (2023). Hybrid Approach for Privacy Enhancement in Data Mining Using Arbitrariness and Perturbation. *Computer Systems Science & Engineering*, 44(3).
32. Pandey, V. K., Mishra, S., Rengarajan, A., Savita, & Roomi, M. M. (2024, March). Enhancing Weather Forecasting with Machine Learning Techniques. In *International Conference on Renewable Power* (pp. 147-156). Singapore: Springer Nature Singapore.
33. Soundappan, S. J. (2025). Next Generation AI Enabled Holistic Cognitive Platform for Secure Cloud Network Intelligence Enterprise Systems and Digital Trust Optimization. *International Journal of Computer Technology and Electronics Communication*, 8(5), 11534-11542.
34. Mathew, A. (2022). Leveraging Big Data Analytics to Power AI and ML (Machine Learning) Automation. *Educational Research (IJM CER)*, 4(5), 131-134.
35. Sugumar, R. (2024). AI-Augmented Quality Engineering for Performance Optimization and Test Orchestration in Distributed Systems. *International Journal of Science, Research and Technology*, 7(5), 12835-12846.
36. Akila, R. (2024). A deep reinforcement learning approach for optimizing inventory management in the agri-food supply chain. *J. Electrical Systems*, 20(4s), 2238-2247.



37. Mahendran, M., Anbazhagan, K., Pavithran, G., Nivas, A., & Pandey, S. D. (2022). Earthquake Damage Prediction using Machine Learning. *Grenze International Journal of Engineering & Technology (GIJET)*, 8(1).
38. Gopinathan, V. R. (2025). Enterprise AI Frameworks for Financial Data Engineering Behavioural Analytics and Intelligent Cloud Solutions. *International Journal of Research Publications in Engineering, Technology and Management (IJRPETM)*, 8(4), 12499-12506.
39. Kondalsamy, P., & Kaliappan, K. (2025). An Optimal Prediction of Leaf Disease Based on Hybrid Deep Learnings and Metaheuristic Technique. *Traitement du Signal*, 42(1), 363.
40. Deivendran, P., Babu, P. S., Malathi, G., Anbazhagan, K., & Kumar, R. S. (2023). Emotion Recognition for Challenged People Facial Appearance in Social using Neural Network. *arXiv preprint arXiv:2305.06842*.
41. Sugumar, R. (2025). Unified AI Framework for Predictive Data Engineering and Real Time Prescription and Billing Systems. *International Journal of Advanced Engineering Science and Information Technology (IJAESIT)*, 8(5), 17261.
42. Vekariya, V., Kumar, S., & Rengarajan, A. (2024). A distinctive and smart agricultural knowledge-based framework using ontology. In *Sustainability in Digital Transformation Era: Driving Innovative & Growth* (pp. 207-213). CRC Press.
43. Gopinathan, V. R. (2025). Software engineering practices for AI-driven systems: From development to deployment (MLOps perspective). *International Journal of Science, Research and Technology*, 8(1), 13493-13500.
44. Mathew, A. R. (2022). Threats and protection on E-sim: a prospective study. *Novel Perspectives of Engineering Research*, 8, 76-81.
45. Naveena, S., & Kavitha, K. (2025). Gossypium herbaceum: Folium disease identification and classification using Efficient Net-Coordinate Convolutional Neural Network (EcoNet). *Engineering Applications of Artificial Intelligence*, 152, 110701.
46. Rengarajan, A., Mishra, A., Kulhar, K. S., Shrivastava, V. P., & Alawneh, Y. J. J. (2024, March). Role of Deep Reinforcement Learning in Mitigating Cyber Security Issues: A Review. In *International Conference on Renewable Power* (pp. 37-48). Singapore: Springer Nature Singapore.
47. Achari, A. P. S. K., & Sugumar, R. (2024, November). Performance analysis and determination of accuracy using machine learning techniques for naive bayes and random forest. In *AIP Conference Proceedings* (Vol. 3193, No. 1, p. 020199). AIP Publishing LLC.
48. Mathew, A., & Alex, H. (2022). Detect & protect-medical device cybersecurity. *Curr. Overview Sci. Technol. Res*, 1, 60-68.
49. Sammy, F., Chettier, T., Boyina, V., Shingne, H., Saluja, K., Mali, M., ... & Shobana, A. (2025). Deep Learning-Driven Visual Analytics Framework for Next-Generation Environmental Monitoring. *Journal of Applied Science and Technology Trends*, 114-122.
50. Anbazhagan, K. (2024). Trustworthy and Adaptive AI Systems for Enterprise Analytics Cybersecurity and Decision Optimization Using API-First and Cloud-Native Architectures. *International Journal of Technology, Management and Humanities*, 10(03), 65-74.
51. Mathew, A. (2021). Deep reinforcement learning for cybersecurity applications. *Int J Comput Sci Mob Compu*, 10(12), 32-38.
52. Dhinakaran, D. (2022). Joe Prathap P. M, Selvaraj D, Arul Kumar D and Murugeswari B, " Mining Privacy-Preserving Association Rules based on Parallel Processing in Cloud Computing,". *International Journal of Engineering Trends and Technology*, 70(3), 284-294.
53. Karthika, K., Anusha, K., Kavitha, K., Harshadha, R., Dharshini, D. S., & Sundhar, N. A. (2025, April). Frequency Reconfigurable Antenna using Advanced Materials: A Study. In *2025 3rd International Conference on Advancements in Electrical, Electronics, Communication, Computing and Automation (ICAECA)* (pp. 1-6). IEEE.
54. Thavamani, C., & Rengarajan, A. (2024). Clustering related behaviour of users by the use of partitioning and parallel transaction reduction algorithm. *International Journal of Advanced Intelligence Paradigms*, 29(2-3), 122-132.
55. Sugumar, R. (2025). Unified AI Framework for Predictive Data Engineering and Real Time Prescription and Billing Systems. *International Journal of Advanced Engineering Science and Information Technology (IJAESIT)*, 8(5), 17261.
56. Soundappan, S. J., & Sugumar, R. (2016). Optimal knowledge extraction technique based on hybridisation of improved artificial bee colony algorithm and cuckoo search algorithm. *International Journal of Business Intelligence and Data Mining*, 11(4), 338-356.
57. SakthiPreetha, A., Kavitha, K., Karthika, K., & Manohari, R. G. (2025, April). A Novel Metasurface-Embedded Antenna for WBAN Communications. In *2025 3rd International Conference on Advancements in Electrical, Electronics, Communication, Computing and Automation (ICAECA)* (pp. 1-4). IEEE.
58. Murugeswari, B., Selvaraj, D., Sudharson, K., & Radhika, S. (2023). Data Mining with Privacy Protection Using Precise Elliptical Curve Cryptography. *Intelligent Automation & Soft Computing*, 35(1).



59. Gopinathan, V. R. (2025). Software engineering practices for AI-driven systems: From development to deployment (MLOps perspective). *International Journal of Science, Research and Technology*, 8(1), 13493-13500.
60. Anbazhagan, K., Kumar, R., Thilagavathy, R., & Anuradha, D. (2024, March). Shortest Job First with Gateway-based Resource Management Strategy for Fog Enabled Cloud Computing. In 2024 4th International Conference on Data Engineering and Communication Systems (ICDECS) (pp. 1-6). IEEE.
61. Kannadhasan, S., Vasuki, S., Kavitha, K., Karthikeyan, P., & Usha, S. G. A. (Eds.). (2025, April). Preface: Role of Artificial Intelligence and IoT in Engineering, Technology & Science [ICRAETS 2024]. In *AIP Conference Proceedings* (Vol. 3258, No. 1, p. 010001). AIP Publishing LLC.
62. Dhinakaran, D., Prathap, P. J., Selvaraj, D., Kumar, D. A., & Murugeswari, B. (2022). Mining privacy-preserving association rules based on parallel processing in cloud computing. *International Journal of Engineering Trends and Technology*, 70(3), 284-294.