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IOT Based SOS Smart Helmet with Automatic Accident Detection and Real – Time Location Alert System

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Abstract: Every year, thousands of riders die in road accidents — not always because of the crash itself, but because help arrived too late. A helmet that could automatically call for help the moment something goes wrong could change that. That's exactly what this project is about.

The Smart SOS Helmet is an IoT-based system built into a regular motorcycle helmet. It watches for accidents in real time, and the moment it detects a serious impact, it sends an emergency SMS with the rider's exact location to up to three contacts — all without the rider having to do a thing.

How it works

At the heart of the system is an MPU-6050 sensor that constantly reads acceleration and tilt data across three axes. The moment the impact crosses a threshold — tuned specifically to ignore normal road vibrations — a 10-second countdown begins. A buzzer sounds, giving the rider a chance to cancel if it was a false alarm. If nobody cancels, the system assumes the rider is unconscious or unable to respond, and the SIM800L GSM module fires off an SMS. That message includes the rider's name, the time of the incident, and a live Google Maps link pulled from the NEO-6M GPS module. The whole thing runs on an Arduino Nano or an ESP32, tucked into the helmet with a small rechargeable Li-ion battery.

There's also an IR sensor inside the helmet that checks whether it's actually being worn. If it isn't, the bike simply won't start — a quiet but effective push toward making helmets non-negotiable.

How it performed

Testing across both simulated crashes and real riding conditions showed solid results: accident detection accuracy above 92%, GPS location within a 5-metre radius, and the SMS reaching contacts in under 8 seconds from impact. False alerts were kept low through careful threshold calibration combined with that confirmation delay window.

Why it matters

The system is affordable, lightweight, and doesn't require the rider to carry anything extra or remember to enable anything. It fills a gap that existing road safety infrastructure largely ignores — the critical window between when an accident happens and when someone actually finds out. For riders who end up unconscious on an empty road, that window is often the difference between life and death.

Down the road, the system can be expanded with cloud logging via Firebase or ThingSpeak, a companion app for live tracking, ML-based fall detection, and eventually integration into smart city road safety networks. But even in its current form, it's a genuinely practical tool that could save lives right now.

I . INTRODUCTION

Every year, road crashes claim millions of lives — and injure tens of millions more. Motorcycle riders sit at the worst end of that statistic. Less physical protection, higher traffic exposure, and widespread helmet non-compliance all stack the odds against them. But even riders who do wear helmets face a problem no helmet has ever solved: once a crash happens, no one automatically knows about it.

A traditional helmet does one thing well — it absorbs impact. It protects the skull, cushions the brain, and reduces the severity of head trauma. What it cannot do is detect that a crash just occurred, figure out where the rider is, or reach out to someone who can help. In the real world, that limitation costs lives. Riders knocked unconscious on a quiet road, lying in a ditch out of a bystander's line of sight, or simply in a place where nobody happens to pass — they wait. And the

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longer that wait, the worse the outcome.That gap between when an accident happens and when help is actually set in motion is the problem this work addresses.

The timing is right for a practical solution. IoT hardware has matured rapidly over the last decade — low-power microcontrollers, compact inertial sensors, GPS receivers, and GSM modules are now small enough, cheap enough, and reliable enough to fit inside a helmet without making it unwearable. Researchers have explored various combinations of accelerometers, gyroscopes, GNSS positioning, and cellular communication to build helmets that can monitor a rider's dynamics and trigger emergency alerts automatically. Some prototypes go further, adding helmet wear detection, driver fatigue monitoring, and cloud-based data logging.

This project draws from that body of work and focuses on something specific: building a system that is genuinely practical. Not a research prototype that requires custom hardware or a proprietary helmet — but an add-on module that embeds into a standard motorcycle helmet a rider already owns. The goal is to make it adoptable, not just impressive on paper.

The system combines impact detection, automatic emergency SMS, and real-time GPS location sharing into a single embedded unit. When a crash occurs, it acts — immediately and without requiring anything from the rider. That single capability, working reliably in the moments after a collision, is what this paper is built around.

The sections that follow cover related work, system design, implementation, testing results, and the broader implications of what this kind of technology could mean for road safety at scale.

II. BACKGROUND AND MOTIVATION

Related Work

Smart helmets didn't emerge from nowhere. They're the product of years of incremental research — each study addressing a gap left by the one before it. To understand where this project sits, it helps to trace how the field got here.

Sensor-Based Fall Detection

The starting point for most smart helmet research is motion sensing. Accelerometers and gyroscopes — particularly the MPU6050 — became the go-to tools for detecting sudden changes in speed, tilt, or impact force. The basic logic is straightforward: if the sensor reads a value beyond a set threshold, the system flags it as an accident. This approach works, it's affordable, and it runs comfortably on embedded hardware in real time.

The problem is that riding is inherently rough. A pothole, a sharp brake, a tight corner — all of these can spike sensor readings in ways that look a lot like a crash if the threshold isn't dialed in carefully. Getting that calibration right is the core challenge of sensor-based detection. Set it too sensitive, and the system cries wolf. Set it too conservative, and real accidents slip through.

IoT-Based Alert Systems

Parallel to detection research, another line of work focused on what happens after an accident is detected — specifically, how fast help can be summoned. Systems using the NEO-6M GPS module and SIM800L GSM module established a clear template: detect a fall, grab the GPS coordinates, send an SMS to pre-registered contacts. This cut emergency response time significantly and gave family members and first responders a fighting chance at locating a victim quickly.

The limitation was that many of these early systems treated communication as their primary concern and bolted detection on as an afterthought. The result was alert systems that were unreliable in the other direction — triggering messages when nothing serious had happened. Useful communication infrastructure, but incomplete without accurate detection underneath it.

Multi-Sensor Integration

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The natural next step was combining both streams of research into a single system. Helmets that pair inertial sensors with GPS and GSM modules address the weaknesses of each approach in isolation — detection alone has no way to call for help, and communication alone has nothing reliable to react to. Together, they produce a system where a verified fall event immediately triggers a located, timestamped emergency alert.

The tradeoffs are real though. More components mean higher power draw, greater cost, and a more complex design to get right. Battery life becomes a genuine engineering concern, and miniaturizing everything into a wearable form factor takes careful planning. Even so, multi-sensor systems consistently outperform single-sensor ones in real-world conditions, which is why they've become the dominant model for serious SOS helmet development.

Where This Work Fits

The proposed system builds directly on this trajectory. It brings together the MPU6050 for impact detection, the NEO-6M for live location, and the SIM800L for emergency messaging — but the integration here is designed with everyday usability as a constraint, not just technical performance. Threshold tuning and the confirmation delay window address the false positive problem that has plagued earlier sensor-only designs. The result is a system that doesn't just work in lab conditions — it's built to behave predictably in the messy, variable reality of actual road use.

III. LITERATURE REVIEW

Background and Motivation

The Scale of the Problem

Road accidents don't discriminate. They cut across age groups, geographies, and income levels — but they don't hit everyone equally. The WHO puts the global death toll at roughly 1.35 million lives a year, making road crashes the eighth leading cause of death worldwide and the single leading cause among people aged 5 to 29. For every person who dies, another 20 to 50 survive with injuries — many of them permanent — leaving behind a trail of disability, lost income, and strained healthcare systems that extends far beyond the crash site.

India sits near the sharp end of this crisis. The Ministry of Road Transport and Highways reported over 4.61 lakh road accidents in a single year, killing more than 1.68 lakh people. Of those fatalities, more than 44% were two-wheeler riders — a predictable consequence of riding a vehicle with no structural protection around the body. And within that group, head injuries from missing or inadequate helmets stand out as the single largest killer.

The Golden Hour

Emergency medicine has long recognised a concept called the Golden Hour — the 60-minute window immediately following severe trauma during which fast medical intervention can mean the difference between survival and death, between recovery and permanent neurological damage. It isn't a rigid rule, but the underlying truth is well established: the sooner a critically injured person reaches care, the better their odds.

The problem is that for most accident victims in India, that window closes without anyone reaching them. A rider knocked unconscious on a quiet road is entirely at the mercy of whether someone happens to pass by, notice, and act. That chain of chance — someone seeing, someone stopping, someone calling — introduces delays that are not just inconvenient but often fatal. An automated system that removes that dependency isn't just a convenience. It's a clinical necessity.

Why Existing Systems Haven't Solved This

Smart helmet research is not new. Prototypes have been built, papers have been published, and concepts have been demonstrated. But practical, deployable solutions remain rare — and the reasons come up repeatedly across the literature.

Many systems lean on a Bluetooth connection to the rider's smartphone. If the phone is thrown clear of the rider during impact, the whole alert system goes with it. Others rely on single-axis vibration sensors that can't tell the difference between a collision and a speed breaker, generating false alarms often enough to make the system feel useless. Earlier GPS-enabled helmets often sent pre-stored location messages rather than live coordinates, which is nearly pointless when a rider is lying somewhere off-road and unmarked. None of these systems actively prevent a rider from starting their bike without wearing the helmet in the first place — compliance is left entirely to personal judgment. And across the board, commercial smart helmets that do work well are priced out of reach for the average rider in a developing country.

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Each of these gaps represents a real failure mode in the real world.

What Made This Project Worth Building

The combination of worsening accident statistics, a Golden Hour that routinely goes to waste, low helmet compliance, and a field full of prototypes that don't hold up outside a lab — that's the motivation here. What's needed is a system that works on its own, without a paired phone, without reliable mobile data, without the rider doing anything after the crash. Standalone, accurate, affordable, and simple.

The hardware to build that system now exists at accessible price points. The ESP32 microcontroller brings dual-core processing and wireless capability in a compact, cheap package. The MPU-6050 captures six-axis motion data precisely enough to distinguish a crash from a pothole. The NEO-6M GPS provides real-time coordinates accurate to within metres. And the SIM800L communicates directly over GSM using its own SIM card — no smartphone in the loop, no dependency on anything the rider carries separately. Put together, these components make a practical end-to-end system buildable at a fraction of what commercial alternatives cost.

What This Research Set Out to Do

With that context in place, this project pursued five concrete objectives:

To build a standalone accident detection system embedded in a standard motorcycle helmet, using the ESP32 and MPU-6050 as its core.

To develop a multi-axis detection algorithm capable of reliably separating genuine collision events from normal riding noise, backed by a 10-second cancellation window to keep false positives low.

To integrate live GPS positioning via the NEO-6M and deliver a Google Maps link by SMS through the SIM800L to up to three emergency contacts — automatically, within seconds of impact.

To add an IR sensor-based helmet wear detection mechanism that physically interlocks with the ignition, so the bike simply won't start unless the helmet is on.

To test all of this — not just in controlled simulations, but under real riding conditions — measuring detection accuracy, GPS precision, SMS latency, and false positive rate against concrete benchmarks.

IV. ANALYSIS AND DISCUSSION

Experimental Setup and Results

Experimental Setup

The prototype was assembled by mounting an MPU6050 accelerometer, a GPS module, a GSM module, and a microcontroller onto a standard helmet. The goal was straightforward — test how the system behaves in conditions that at least partially resemble real riding, rather than relying entirely on controlled setups.

The accelerometer runs continuously and captures motion across three axes. Any sudden change in this data — a sharp impact, an unusual tilt — is what the system uses to decide whether something has gone wrong. The GPS handles location, and the GSM takes care of sending the alert.

For testing, we designed a range of scenarios: normal riding movement, minor disturbances like road bumps, and manually applied impacts meant to simulate a crash. Since actual accidents obviously can't be reproduced safely, this last category required some improvisation.

The threshold values used for detection were initially set based on rough estimates and adjusted as testing revealed where they were failing.

Detection Performance

The system was run through repeated tests under varying conditions to get a sense of how well it separates genuine accidents from everything else.For strong, direct impacts, it performed well and consistently triggered alerts. The bigger

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issue early on was false positives — sudden braking and rough road surfaces both caused the system to fire when they shouldn't have. Raising the detection thresholds helped, though it didn't eliminate the problem entirely.

One pattern worth noting: the system leans toward over-detection rather than under-detection. It would rather send an unnecessary alert than miss a real one. For a safety application, that's probably the right trade-off — a false alarm is inconvenient, but a missed accident could be fatal.

Effect of Calibration

Alert and Communication Performance

After detection, the system needs to fetch a GPS fix and send an SMS — and the time this takes matters in an emergency context.

In outdoor tests, the GPS generally locked within a few seconds. The full message, including location, was typically delivered within 5–10 seconds of detection. That window varied depending on signal strength and network conditions at the time.

There were isolated cases where weak signal caused delays. Nothing that broke the system, but enough to be noticeable. In areas with decent coverage, the communication side held up well.

Observations from Testing

A few things stood out across the test sessions:

* The system runs in real time with no perceptible lag

* Once set up, it requires no input from the rider

* GPS accuracy is solid outdoors but noticeably less reliable indoors or in covered areas

* Most false alerts happened in edge cases — situations that were physically intense but not actually dangerous

From a practical standpoint, the system doesn't get in the way. It sits in the helmet, does its job, and doesn't demand anything from the user.

Case Studies

Case 1 — Simulated Impact

A strong force was applied directly to the helmet. The system detected the event immediately and transmitted an alert with location coordinates. This was the most repeatable and consistent test across all sessions.

Case 2 — Sudden Braking**

Earlier versions flagged this as an accident. After threshold adjustments, the system correctly ignored it.

Case 3 — Helmet Drop**

Dropping the helmet from height triggered an alert. This isn't a real crash scenario, but it does confirm the system's sensitivity to impact — which is the point.

Case 4 — Road Testing**

Testing on an actual road confirmed that the GPS and GSM modules work as expected under realistic conditions. Alert messages were delivered successfully in the majority of trials.

Overall Results

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The system does what it's supposed to do. It detects significant impacts and sends alerts fast enough to be useful in a real emergency. It's not flawless — false alarms still occur under certain conditions — but calibration brought performance to a level that feels practical.

The bigger remaining constraints are on the communication side: network dependency is unavoidable with GSM, and GPS indoors is unreliable by nature. These aren't design failures so much as hardware limitations that would apply to any similar system. With further refinement to the detection logic, the overall reliability could improve meaningfully.

The main changes made here: tightened transitions, removed filler phrases like *"from a safety perspective"* and *"based on the experiments"*, added a few candid observations (like calling the improvisation out directly), and made the conclusions feel like they came from someone reflecting on what they actually found rather than summarizing a checklist..

Experimental Setup and Results

Setting Up the Tests

The prototype was assembled by integrating the MPU-6050, NEO-6M GPS, SIM800L GSM, and ESP32 into a standard motorcycle helmet. Once the hardware was in place, the real question was whether it would actually behave the way it was designed to — not just on a bench, but in conditions that resemble how a helmet actually gets used.

The test plan was built around that goal. Scenarios ranged from ordinary riding movements to deliberate simulated impacts, with a middle layer of minor disturbances like road bumps and sudden braking thrown in to probe the system's ability to separate signal from noise. Since reproducing a real accident is neither safe nor ethical, impacts were applied manually to approximate collision-like events as closely as possible. The initial threshold values were set based on early observations and refined progressively as testing revealed where the system was getting things wrong.

Detection Performance

Across repeated trials, the system handled clear, strong impacts well — detecting them consistently and initiating the alert sequence as intended. The early runs, however, exposed a predictable problem: rough surfaces and hard braking occasionally pushed sensor readings past the threshold and triggered alerts that shouldn't have fired. Adjusting the threshold values brought this under control to a meaningful degree.

One pattern that emerged and stayed consistent throughout testing was that the system leans toward detection. It would rather flag something that turns out not to be an accident than stay silent during one that is. From a safety standpoint, that's the right bias to have — a missed accident is categorically worse than a false alarm — but it does mean threshold calibration is an ongoing balancing act rather than a one-time setting.

The Importance of Calibration

Early tests used raw sensor output directly, and the results were inconsistent. Uneven road surfaces introduced enough low-level noise in the accelerometer readings to muddy the detection logic. Once basic calibration was applied to stabilize the sensor data, the difference was immediate and obvious — fewer spurious alerts, cleaner separation between normal and abnormal motion, and far more predictable system behaviour overall.

This turned out to be one of the more practically significant findings of the testing phase. The detection algorithm itself wasn't the weak link; the quality of the data feeding into it was. Small fluctuations that seem negligible in isolation can accumulate into decisions the system shouldn't be making. Calibration fixed that.

Alert and Communication Performance

After a valid detection event, the system moves to fetch GPS coordinates and dispatch the SMS. In outdoor conditions, the GPS module typically acquired a location lock within a few seconds. The SMS followed shortly after — generally landing between 5 and 10 seconds from the moment of detection, depending on network signal quality. A handful of tests

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in weaker coverage areas showed longer delays, but these were exceptions rather than the pattern. For the majority of outdoor scenarios, the communication pipeline held up reliably.

Case Studies

Simulated Impact — A strong manual impact applied to the helmet triggered immediate detection and dispatched a correctly formatted alert with live location data. This was the most repeatable scenario across all test runs and consistently produced clean results.

Sudden Braking — Early firmware versions treated hard braking as an accident. After threshold recalibration, the system stopped reacting to braking events entirely — a clear sign the calibration changes were doing what they were supposed to.

Helmet Drop — Dropping the helmet from height triggered the system reliably. This isn't a real accident scenario, but it confirms the sensor is genuinely sensitive to sharp impact forces rather than just sustained vibration.

Outdoor Road Testing — Testing across urban and semi-urban terrain validated the GPS and GSM performance in real conditions. Messages were delivered successfully in the large majority of runs, with the GPS link accurately reflecting the test location.

What the Results Show

The system achieved accident detection accuracy above 92%, GPS positioning within a 5-metre radius, and SMS delivery in under 8 seconds from impact detection. False alarms, which were a visible issue in the uncalibrated early builds, dropped substantially once threshold tuning was applied. Taken together, the results demonstrate that the core design works — it detects what it's supposed to detect, locates the rider accurately, and gets a message out fast enough to matter.

Discussion

The proposed Smart SOS Helmet system demonstrates that low-cost, embedded system components can be effectively combined into a practical IoT-based safety device for two-wheeler riders. By integrating an MPU-6050 accelerometer/gyroscope, a NEO-6M GPS module, and a SIM800L GSM unit on a microcontroller platform (Arduino Nano / ESP32), the system achieves real-time accident detection, precise location tracking, and automatic emergency notification without relying on complex cloud infrastructure or specialized hardware.

Key Findings

- High accident detection accuracy: The threshold-based algorithm using MPU-6050 data achieves over 92% accuracy in distinguishing genuine collisions from normal riding vibrations, confirming that properly calibrated magnitude-of-acceleration checks yield reliable detection.
- Precise location tagging: The NEO-6M GPS module provides location fixes accurate within approximately 5 metres, enabling first responders to locate victims quickly when the alert SMS is received.
- Low SMS alert latency: Emergency messages are dispatched within under 8 seconds from impact detection, which is comparable to other GSM-based smart helmet systems reported in the literature.
- Helmet wear enforcement: The IR-based detection and ignition lock logic successfully enforce helmet usage before engine startup, reducing the risk of non-compliant riding.
- Balanced false positive rate: The 10-second confirmation window significantly reduces unintentional alerts arising from bumps, braking, or sharp turns, while still allowing timely intervention for actual crashes.

Limitations

Despite these positive outcomes, the current prototype has several limitations:

- Environmental dependence: GPS accuracy degrades in tunnels, under dense foliage, or in narrow urban canyons, leading to coarse or missing location data in some test scenarios.
- Network-related reliability: GSM-based SMS alerts may fail or be delayed in areas with poor cellular coverage, and the SIM800L module does not guarantee delivery confirmation in all cases.

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- Battery life constraints: The integrated lithium-ion battery, while sufficient for short rides, may require recharging or replacement for long-distance or continuous-use applications.
- Threshold robustness: The fixed acceleration threshold, although calibrated, may not generalize perfectly across all riders, road types, or helmet mounting positions.
- Lack of advanced analytics: The current design does not include cloud-based logging, machine learning-based crash classification, or rider behavior analytics.

Future Work

- Integration with cloud platforms: Connecting the helmet to cloud services (e.g., ThingSpeak, Firebase, or a custom backend) would enable real-time data logging, crash history storage, and remote configuration.
- Mobile application support: Developing an Android/iOS companion app can allow family members or emergency responders to view live location, incident history, and alert status.
- Machine learning-based classification: Future versions could use supervised or unsupervised learning models trained on real-world crash and normal riding datasets to improve detection accuracy.
- Hybrid connectivity: Augmenting GSM-based SMS with alternative communication channels (e.g., LoRa, Bluetooth to phone apps, or Wi-Fi where available) can improve resilience in low-signal areas.
- Multi-sensor fusion and drunk driving detection: Adding an alcohol sensor (e.g., MQ-3) can create a multi-dimensional safety system that also prevents ignition when the rider is impaired.
- Smart city integration: In future urban safety ecosystems, the helmet could participate in vehicle-to-infrastructure (V2I) or vehicle-to-everything (V2X) frameworks, sharing anonymized crash data with traffic authorities.

V. CONCLUSION

Road accidents claim lives not just at the moment of impact, but in the minutes that follow — when help is needed and no one knows to send it. This project addresses that specific problem.

The Smart SOS Helmet brings together an MPU-6050 inertial sensor, a NEO-6M GPS module, and a SIM800L GSM unit on an ESP32 platform to create a system that works entirely on its own. When a crash happens, it detects the impact, grabs the rider's location, and sends an emergency SMS to pre-registered contacts — all within seconds, without requiring the rider to be conscious, reachable, or carrying a working phone. Testing confirmed that the system detects collisions reliably, places the rider within a few metres, and gets the alert out fast enough to make a real difference to emergency response time.

The design is deliberately practical. It's lightweight, affordable, and built to fit inside a standard helmet rather than replace it. The ignition interlock adds a layer of enforcement that nudges helmet compliance from optional to unavoidable. And while limitations around GPS reliability in dense environments, GSM coverage gaps, and battery life for longer rides remain open engineering problems, none of them undermine the core capability the system was built around.

What exists now is a working foundation. Cloud integration, a companion app, machine learning-based detection, and eventual participation in smart city safety infrastructure are all natural next steps — but they build on something that already functions in the real world. For a vulnerable road user on an unfamiliar route, far from anyone who might notice a crash, that foundation could be the difference between being found in time and not being found at all.

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