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SENTRI: Safety and Emergency Network for Two-Wheeler Response Intelligence

Ganavi K
1KT23EC008
Dept. of ECE
Sri Krishna Institute of Technology
Bengaluru, India

Gurunanda S
1KT23EC009
Dept. of ECE
Sri Krishna Institute of Technology
Bengaluru, India

Mohit Kumar
1KT23EC027
Dept. of ECE
Sri Krishna Institute of Technology
Bengaluru, India

Tejashwini Prakash Babu
1KT23EC055
Dept. of ECE
Sri Krishna Institute of Technology Bengaluru, India

Mr Nagaraj
Guide, Associate Professor
Dept. of ECE
Sri Krishna Institute of Technology Bengaluru, India

Abstract - Riding a two-wheeler without a helmet, or without a firm hold on the handlebar, puts the rider at serious risk. Most safety systems react only after an accident has happened. This paper presents SENTRI (Safety and Emergency Network for Two-Wheeler Response Intelligence), a bench prototype that tries to act before an accident. An ESP32 controller reads an MPU6050 motion sensor, a helmet switch and two capacitive grip sensors. Ignition is released only when the helmet is worn and the vehicle is at rest. If a hand leaves a grip while the vehicle is moving, a four-stage escalating alert starts. The buzzer and alert LED become faster at each stage, a throttle reduction is applied at the third stage, and an emergency message is raised at the fourth. Placing the hand back, or stopping the vehicle, resets the alert at once. Status is shown on an SSD1306 OLED. In the present prototype the throttle reduction and the emergency message are simulated. [INSERT: one sentence on the measured bench result.]

Index Terms - two-wheeler safety, helmet interlock, capacitive grip sensing, ESP32, MPU6050, embedded systems.

I. INTRODUCTION

A two-wheeler rider has very little physical protection. The helmet is the main safeguard for the head, and the two hands on the grips are the only way the rider steers, brakes and controls the throttle. If the helmet is not worn, or if one or both hands leave the handlebar while the vehicle is moving, the chance of a serious accident rises. Neither condition is checked by a conventional two-wheeler.

A large share of the safety systems described for two-wheelers focus on what happens after an incident: a fall or impact is detected and an alert is sent [1]–[4]. These systems are useful, but they cannot undo the first moments of the accident. A complementary idea is to watch the rider's behaviour before anything goes wrong, and to warn the rider early and in steps.

SENTRI follows that idea. It combines three simple checks in one low-cost embedded platform: whether the helmet is worn, whether the vehicle is moving, and whether the hands are on the grips. The helmet decides whether ignition is released. The motion sensor and the grip sensors together decide whether an alert is needed. The alert then grows through four stages, so that a short lapse gives only a gentle warning, while a long lapse leads to a throttle reduction and an emergency message. The work reported here is a bench prototype built by a final-year project team, and it is described honestly in terms of what is working and what is simulated.

The rest of this paper is organised as follows. Section II gives the review scope. Section III reviews the related work. Section IV compares it with SENTRI. Sections V and VI state the research gap and the proposed approach. Section VII describes the design. Section VIII discusses the results and limits, and Section IX concludes.

II. REVIEW SCOPE AND METHODOLOGY

The review looks for published work that is close to one or more parts of SENTRI. The search themes were: smart helmet systems, ignition control for two-wheelers, accident detection and alerting, accelerometer-based motion sensing, and hands-on detection for steering wheels and handles. IEEE Xplore was the first source. Closely related open publications were added where they

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gave direct evidence for a design choice.

Each paper was screened against four questions: (i) does it work on a two-wheeler or a similar vehicle, (ii) does it run on an embedded or low-cost platform, (iii) does it act before or after an accident, and (iv) does it sense the helmet or the rider's hands. The review is small and focused. It does not claim to list every paper on the topic.

III. RELATED WORK

A. Ignition Control and Accident Alert

The work in [1] addresses smart ignition control together with an accident alert for two-wheelers, as its title states. It is the closest published idea to the helmet-locked ignition used in SENTRI. [INSERT: after reading the abstract of [1], add one sentence on its method and one on its reported result.]

B. IoT-Integrated Smart Helmets

Reference [2] presents IoT-integrated smart helmet technology for human safety, and [3] presents an IoT-based smart helmet for crash detection, prevention and rider safety monitoring. Both place the intelligence in or around the helmet. SENTRI instead keeps the helmet as a simple switch and puts the logic on the vehicle side.

[INSERT: add one sentence each on the sensors and the alert method used in [2] and [3].]

C. Accelerometer-Based Accident Detection

Reference [4] describes a vehicle accident detection system that uses an accelerometer. Accelerometer data is also the basis of the motion check in SENTRI, although SENTRI uses it to decide whether the vehicle is moving, not to detect an impact. [INSERT: add the threshold or algorithm reported in [4] if it is stated.]

D. Hands-On Detection for Steering Wheels

Hollmer and Fischer describe hands-on detection for steering wheels using a capacitive sensor mat [5]. Neural networks (a time-delay network, an LSTM and a random forest) classify gradient data from the capacitance readings. A time-delay network with 50 hidden neurons was ported to an STM32F769 microcontroller. The reported reaction times were 108–294 ms with two fingers and 74–94 ms with four fingers. Two-finger detection was unreliable on the inside of the wheel [5]. This work shows that capacitance is a workable signal for hand presence. SENTRI uses the same physical idea in a much simpler form: a bare wire on a general-purpose pin, a charge-time reading and a learned baseline.

IV. COMPARATIVE ANALYSIS

Table I places the reviewed work next to SENTRI. The “focus” column is taken from each paper's title. Entries marked [INSERT] must be completed after the abstracts are read.

TABLE I. COMPARISON WITH RELATED WORK

Ref	Focus (from title)	Relation to SENTRI
[1]	Ignition control and accident alert, two-wheeler	Closest in goal. [INSERT: does it check hands or helmet before a crash?]
[2]	IoT smart helmet for human safety	Logic in helmet. [INSERT]
[3]	IoT smart helmet: crash detection, prevention, monitoring	Prevention is in scope. [INSERT]
[4]	Accident detection using an accelerometer	Same sensor family, different use. [INSERT]
[5]	Hands-on detection, capacitive mat, neural networks	Same signal type; heavier method.
This work	**Helmet interlock, grip monitoring, 4-stage alert**	**Bench prototype; throttle cut and SMS simulated.**

V. RESEARCH GAP ANALYSIS

1) Reaction after the event. The accident-alert work reviewed here is mainly about informing someone once an incident is detected. SENTRI moves the check earlier, to the moment a hand leaves the grip. [INSERT: confirm this against the abstracts of [1]–[4].]

2) Helmet and hands treated separately. The helmet and the grips are two different signs of how safely the rider is riding. SENTRI links them in one decision chain: the helmet gates the ignition, and the grips gate the alert.

3) One-step alarms. A single alarm cannot tell a brief lapse from a long one. SENTRI uses four stages of three seconds each, so that the response grows with the time the hands stay off.

4) Heavy sensing methods. Hand detection in the literature uses a sensor mat and a trained network on a 32-bit controller [5]. A simpler option is worth testing on cheap hardware, even if it is less robust.

5) Limits of this prototype. The grip sensing needs the rider's body to be grounded, the throttle reduction and the emergency message are simulated, and no road tests were done. These limits are stated so that the claims in this paper stay within what was built.

VI. PROPOSED SYSTEM

SENTRI is a layered design on one ESP32 board: (1) a helmet switch that gates the ignition, (2) an MPU6050 motion check, (3) two capacitive grip sensors, (4) a decision rule that combines them, (5) a four-stage buzzer and LED alert, and (6) an OLED status display. Two outputs that a real vehicle would need, the throttle reduction and the emergency message, are shown in simulation. Fig. 1 gives the block diagram.

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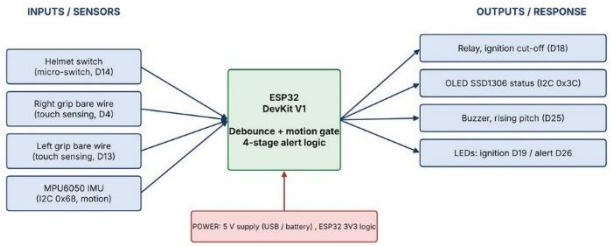


Fig. 1. Block diagram of SENTRI.

VII. SYSTEM DESIGN AND IMPLEMENTATION

A. Hardware

The controller is an ESP32 DevKit V1 [7]. The MPU6050 [6] and the SSD1306 OLED share one I2C bus. The helmet switch and the two grip wires use plain input pins. Table II lists the connections that are fitted. A servo, a throttle potentiometer, a GSM module and a GPS module are not fitted in this prototype.

TABLE II. FITTED COMPONENTS AND PINS

Component	ESP32 pin	Role
MPU6050	SDA D21, SCL D22 (0x68)	Motion sensing
SSD1306 OLED	SDA D21, SCL D22 (0x3C)	Status display
Helmet switch	D14 (pull-up)	Helmet worn or not
Right grip wire	D4	Right hand sensing
Left grip wire	D13	Left hand sensing
Relay	D18 (active high)	Ignition stand-in
Ignition LED	D19	Ignition state
Buzzer	D25	Audible alert
Alert LED	D26	Visual alert

B. Helmet Interlock

The helmet switch is read with the internal pull-up, so a pressed switch means the helmet is not worn. The switch is read only when the vehicle is at rest, after a 300 ms debounce. If the helmet is worn at rest, the relay releases the ignition and the OLED shows a PROCEED message for 3 s. If the helmet is taken off while the vehicle is moving, the ignition is not cut, because cutting power at speed would itself be dangerous. A blinking HELMET REMOVED warning is shown instead.

C. Motion Detection

The MPU6050 acceleration magnitude is compared with 1 g. The vehicle is treated as moving when

$$| \sqrt{(a_x^2 + a_y^2 + a_z^2)} - 1\,g | > 0.20\,g \qquad (1)$$

VIII. RESULTS AND DISCUSSION

A. Functions Verified on the Bench

The following functions were seen working on the bench prototype: the helmet switch and the ignition release, the and it stays in the moving state for 1.5 s after the last motion, so short pauses do not flip the state.

D. Grip Sensing by Charge Time

Each grip has a bare wire on its own pin. The pin is driven low to empty the wire, then switched to input with the internal pull-up. The processor counts clock cycles until the pin reads high. The charge time follows

$$t \propto R_{pu} \cdot (C_{wire} + C_{hand}) \qquad (2)$$

where R_{pu} is the pull-up resistance, C_{wire} is the capacitance of the wire and pin, and C_{hand} is the extra capacitance added by a hand. A hand therefore lengthens the count. Forty readings are averaged. A baseline is learned at start-up with the hands off (about 2 s) and follows slow drift while no hand is present. A hand is “placed” when the reading exceeds the baseline by a margin of max(40 counts, 3 % of baseline). A hand is “removed” only after it has been gone for 400 ms. The method needs the rider's body to share a ground with the circuit.

E. Alert Escalation

An alert is valid when at least one grip reads removed, the vehicle is moving and the ignition is on. Each stage lasts 3 s. Table III gives the stage settings and Fig. 2 the flow of the logic.

TABLE III. ALERT STAGES

Stage	Starts at	Beep period	Tone	Extra action
1	valid	1000 ms	2000 Hz	Alert LED blinks
2	+3 s	700 ms	2400 Hz	None
3	+6 s	450 ms	2800 Hz	Throttle cap (sim.)
4	+9 s	300 ms	3200 Hz	Mock SMS

At Stage 3 the throttle cap falls by 5 % every 100 ms down to 30 %. This is shown on the OLED and is not connected to a real throttle. At Stage 4 a mock message with a fixed location link is printed on the serial monitor. Placing a hand back, or stopping the vehicle, resets the stage to zero and the cap recovers by 10 % every 100 ms.

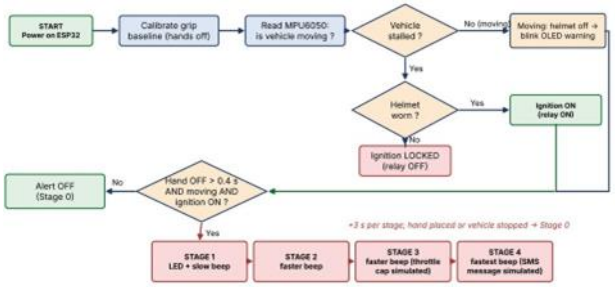


Fig. 2. Flow chart of the SENTRI logic.

F. Display and Demonstration Modes

The OLED shows the vehicle state, the helmet state, which grip is off and the alert stage. For demonstration, the

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firmware accepts serial keys that force the motion or grip state. These keys are used only to repeat a scenario on the bench and are not part of the sensing. left and right grip sensing, the buzzer, and the motion detection. [INSERT: confirm whether the OLED display and the alert reset were also tested.] Grip sensing was less steady than the other functions and depended on the body being grounded. [INSERT: number of trials per function and how many passed.]

B. Alert Timeline

Fig. 3 shows the alert stage and the simulated throttle output against time. It is drawn from the timing constants in the firmware, not from a logged run, and the throttle trace is simulated.

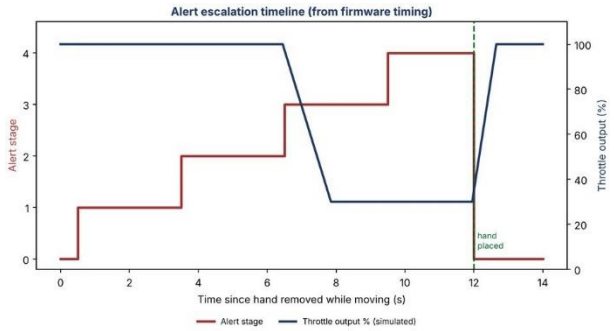


Fig. 3. Alert escalation timeline from firmware timing (throttle is simulated).

C. Measured Readings

TABLE IV. GRIP READINGS (TO BE FILLED)

Quantity	Left grip	Right grip
Baseline (counts)	[INSERT]	[INSERT]
Hand placed (counts)	[INSERT]	[INSERT]
Detection delay (ms)	[INSERT]	[INSERT]
Trials passed	[INSERT]	[INSERT]

D. Limitations

The grip wires are a low-cost prototype and are sensitive to grounding and noise. The throttle reduction and the emergency message are simulated. GSM, GPS and a servo throttle are not fitted. No road test has been done, and the thresholds were set by hand on the bench. These points limit how far the present results can be applied to a real vehicle.

IX. CONCLUSION AND FUTURE SCOPE

SENTRI shows that a helmet interlock, a motion check and two capacitive grip sensors can be combined on one ESP32 to give an early, stepped warning to a two-wheeler rider. The helmet, the grip sensing, the buzzer and the motion detection work on the bench, and the throttle reduction and the emergency message are simulated.

Future work includes a real throttle limiter, GSM and GPS for a real emergency message, a more robust grip sensor such as a dedicated touch IC or a pressure sensor, data logging and a printed circuit board, crash detection from the same motion sensor, and road tests to tune the thresholds.

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