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Two-Wheeler Monitoring System for Real-Time Jerk Detection and Rider Alerting Using an Arduino-Based Embedded Device

Rishabh Shah

Ahmedabad International school

Abstract
Two-wheeler riders are highly exposed to unsafe riding conditions caused by sudden road irregularities, abrupt braking, and unstable vehicle motion. This paper presents the design and evaluation framework of a low-cost Two-Wheeler Monitoring System that detects sudden jerk events and provides real-time rider alerts using an Arduino-based smart device mounted on the speedometer. The proposed system integrates an Arduino Nano, MPU-6050 accelerometer–gyroscope module, 16×2 liquid crystal display (LCD) with inter-integrated circuit (I2C), buzzer, NeoPixel light-emitting diode (LED), and two button-size vibration motors. The Arduino continuously reads inertial data from the MPU-6050 and computes a jerk score from the change in acceleration magnitude. When the jerk score crosses the predefined threshold, where the given project threshold is interpreted as "range to 1," the event is classified as JERK. The LCD displays "Jerk detected," the NeoPixel turns red, the buzzer sounds, and the vibration motors activate. During normal riding, the LCD displays "Normal state" and a computed jerk value. A compact enclosure was computer-aided designed (CAD) and fabricated using polylactic acid (PLA) through three-dimensional (3D) printing for speedometer mounting. Because full field validation was not conducted, this paper presents a methodology and illustrative sample dataset rather than claiming real-world experimental performance. The proposed prototype demonstrates a practical embedded approach for real-time rider feedback and provides a foundation for future adaptive calibration, logging, and Internet of Things (IoT)-enabled safety extensions.

Keywords: Arduino Nano, MPU-6050, two-wheeler safety, jerk detection, inertial measurement unit, embedded systems, rider alerting, intelligent transportation systems

1. Introduction

Two-wheelers are widely used for personal mobility because of their low cost, maneuverability, and suitability for congested roads. However, riders are comparatively more vulnerable than occupants of enclosed vehicles because they have limited structural protection, reduced contact area with the road, and direct exposure to sudden disturbances. Global road-safety literature consistently identifies vulnerable road users, including riders of powered two- and three-wheelers, as a major concern in traffic-injury prevention (World Health Organization [WHO], 2023). In intelligent transportation systems (ITS), low-cost sensing and real-time feedback can support rider awareness by detecting unusual vehicle motion and notifying the rider immediately.

Inertial measurement units (IMUs), including accelerometers and gyroscopes, are commonly used to capture vehicle vibration, orientation, acceleration, and road-induced motion. Previous studies have shown that accelerometer and gyroscope signals can be used to detect road anomalies, estimate road condition, classify driving behavior, and support safety monitoring (Allouch et al., 2017; Carlos et al., 2018; Khandakar et al., 2025; Vlahogianni & Barmpounakis, 2017). The present project applies this concept to a compact embedded two-wheeler device that detects sudden jerks and alerts the rider through visual, audio, and haptic feedback.

2. Literature Review

Road-safety research emphasizes the need for preventive and responsive safety systems for vulnerable road users. Powered two-wheeler riders face higher injury risk because the rider's body is directly exposed during instability or collision. WHO (2023) highlights the continuing global burden of road-traffic injuries and the importance of interventions that improve user safety. For two-wheelers, embedded monitoring can support safety by detecting abnormal vehicle dynamics before or during unsafe events.

Inertial sensing has been widely explored for road-condition monitoring. Smartphones and embedded IMU devices can capture accelerometer and gyroscope signals that reflect potholes, bumps, vibration, roughness, and aggressive motion (Allouch et al., 2017; Carlos et al., 2018; Khandakar et al., 2025). RoadSense, for example, used smartphone accelerometer and gyroscope signals to estimate road conditions (Allouch et al., 2017). Other work has evaluated accelerometer-based road anomaly detection approaches and highlighted the importance of signal representation, segmentation, and thresholding (Carlos et al., 2018; Chen et al., 2019; Zheng et al., 2020).

Although many prior systems use smartphones or cloud-based machine learning, the present work focuses on a simple embedded system that operates locally on a two-wheeler without requiring internet connectivity. This design choice improves response immediacy and reduces system complexity.

Real-time feedback is important in safety-critical embedded systems. A rider alert can be visual, auditory, haptic, or a combination of these modes. A display provides state information, an LED provides rapid visual warning, a buzzer provides audio warning, and vibration motors provide haptic feedback. The use of multiple alert channels can improve noticeability, especially in a noisy traffic environment. In the proposed system, the LCD communicates the state, the NeoPixel turns red during jerk detection, the buzzer sounds, and the vibration motors activate.

Existing road anomaly and ride-quality systems often focus on data collection, cloud processing, smartphone sensing, or infrastructure mapping. The identified gap is a compact, low-cost, vehicle-mounted embedded device that directly informs the rider of sudden jerk conditions in real time. This work addresses that gap by implementing local sensing, threshold classification, and immediate multimodal feedback using Arduino-compatible components.

3. System Architecture and Hardware

The proposed system consists of five main blocks: sensing, processing, decision-making, alerting, and enclosure/mounting. The MPU-6050 senses two-wheeler motion and sends acceleration and gyroscope data to the Arduino Nano through the I2C bus. The Arduino Nano reads the sensor values, computes a jerk score, compares the score with a threshold, and classifies the condition as either normal or jerk detected. The LCD displays the current state, the NeoPixel LED gives color feedback, and the buzzer generates an acoustic alert along with the vibration motors haptic feedback receive on both the hands of driving vehicles during unsafe conditions.

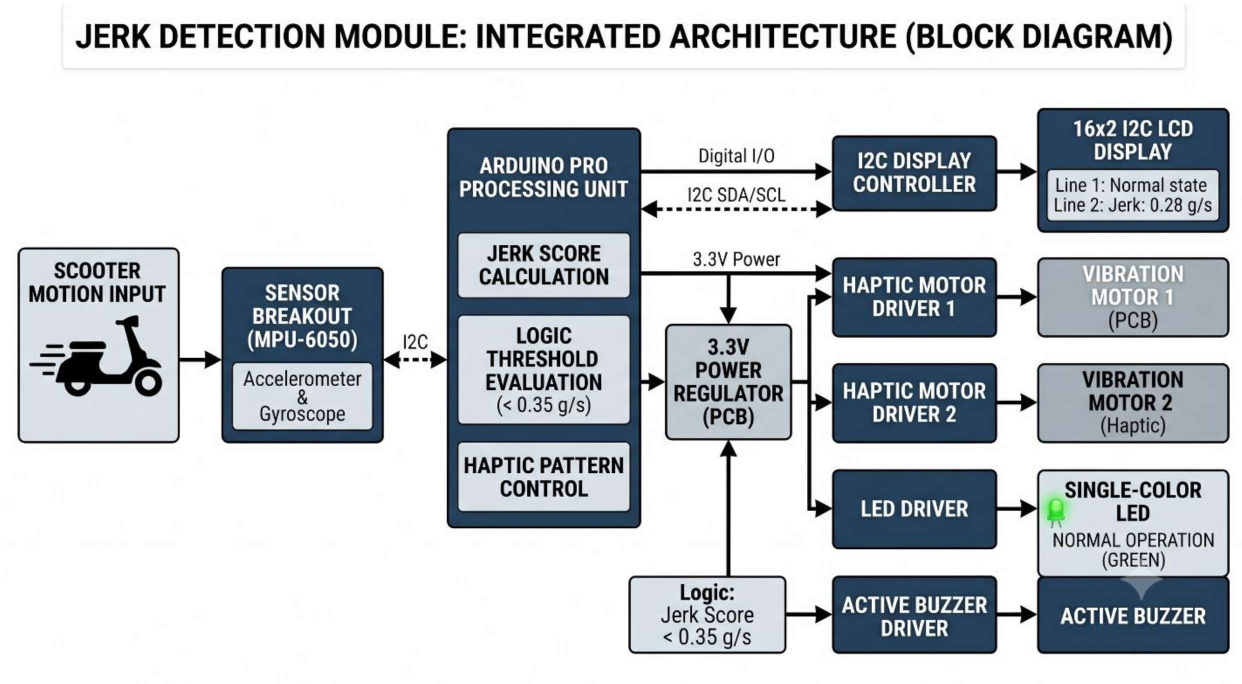

Figure 1:- Block diagram of Two-wheeler jerk detection system

The hardware uses the Arduino Nano as the central embedded controller. The MPU-6050 is selected because it combines accelerometer and gyroscope measurements in a compact module. The 16×2 LCD with I2C interface reduces wiring complexity compared with parallel LCD connections. The buzzer provides an audible warning, while the NeoPixel LED provides a strong visual indication. The complete device is intended to be mounted on the speedometer section so that the rider can see the display and LED without shifting attention away from the riding direction.

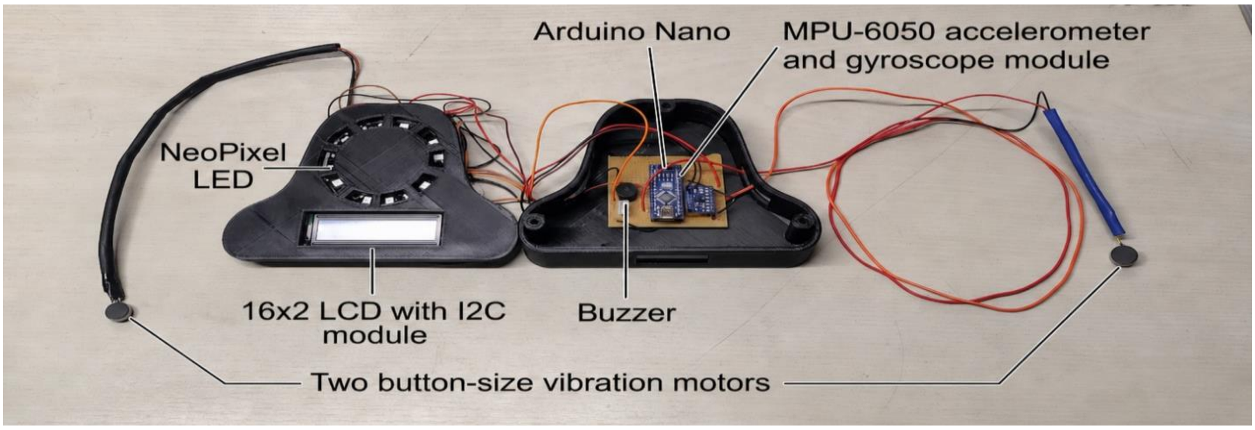

Figure 2:- 3D Printed POC with Component Labelled

The enclosure was designed using CAD and fabricated using PLA through 3D printing. The enclosure must protect the Arduino Nano, MPU-6050, display connections, buzzer, LED, and vibration motor wiring while allowing the LCD and LED to remain visible. Mounting on the speedometer requires a compact form factor, stable attachment, and sufficient clearance so that the device does not block critical vehicle indicators.

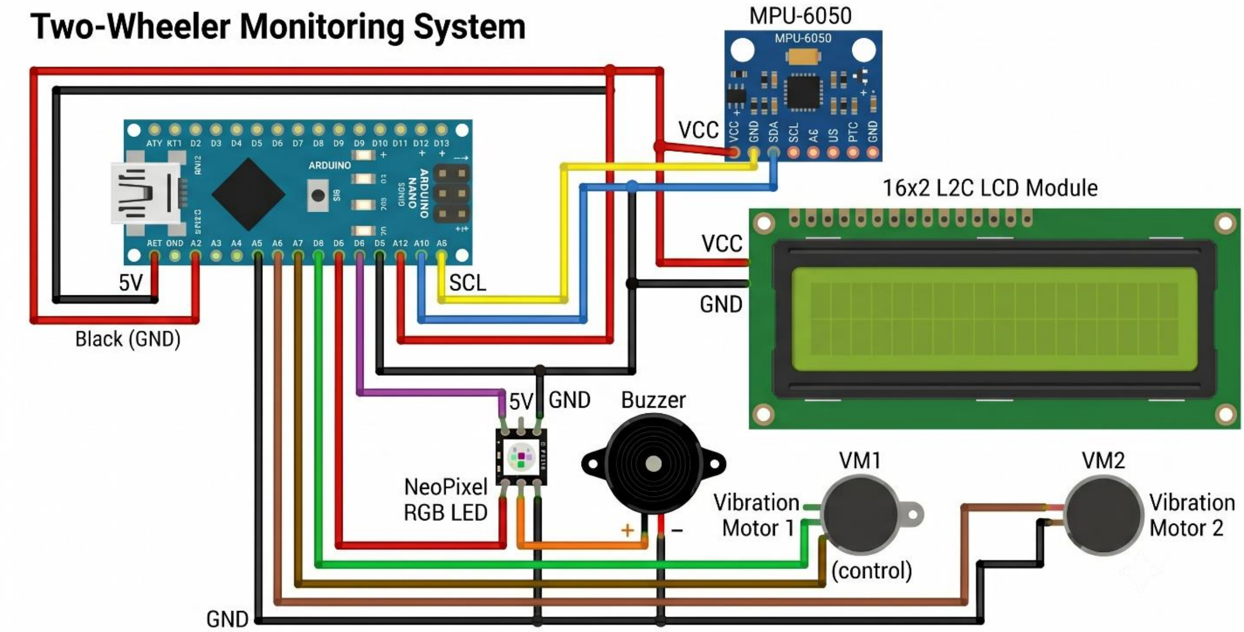

Figure 3:- Circuit diagram

4. Experimental Setup and Evaluation

4.1 Conditions

Condition 1: Normal riding.

This condition represents smooth riding or minor vibration where the jerk score remains below the threshold.

Condition 2: Jerk/unsafe condition.

This condition represents sudden jolts or abrupt motion where the jerk score crosses the threshold of 1.00.

4.2 Metrics

The following metrics are proposed for evaluation:

1. Jerk score: The computed normalized value from acceleration magnitude changes.
2. State label: Normal or JERK based on the threshold.
3. Alert response: Whether LCD, NeoPixel, buzzer, and vibration motors respond correctly.
4. Detection latency: Time between threshold crossing and alert activation.

5. False alert rate: Number of jerk detections during normal riding.
6. Missed detection rate: Number of unsafe jerk events not detected.

4.3 Limitations

No real-world experimental dataset was provided. Therefore, the graphs and dataset in this paper are synthetic sample data for illustration only and must not be interpreted as validated field results. The threshold value of 1.00 requires calibration for different motorcycles, mounting positions, sensor orientations, road conditions, and rider behaviors.

5. Methodology

The proposed Two-Wheeler Monitoring System follows a real-time embedded sensing and alerting methodology. The Arduino Nano continuously reads acceleration data from the MPU-6050 accelerometer and gyroscope sensor mounted inside the PLA enclosure on the two-wheeler speedometer. The acceleration values along the x, y, and z-axes are used to calculate the acceleration magnitude, and the change between consecutive acceleration magnitudes is used to estimate a normalized jerk score. Based on the project threshold, the jerk detection limit is assumed to be 1.00. If the computed jerk score is less than 1.00, the system classifies the riding condition as normal, displays "Normal state" on the 16×2 I2C LCD, and shows "Jerk: 0.00" or the computed jerk value on the second line. If the jerk score is equal to or greater than 1.00, the system classifies the condition as **JERK** and immediately activates the alert outputs. In this state, the LCD displays "Jerk detected," the NeoPixel LED turns red, the buzzer produces an audio warning, and the two button-size vibration motors provide haptic feedback to the rider. This methodology enables the prototype to detect sudden unsafe riding motion and alert the rider in real time using a simple threshold-based embedded decision logic.

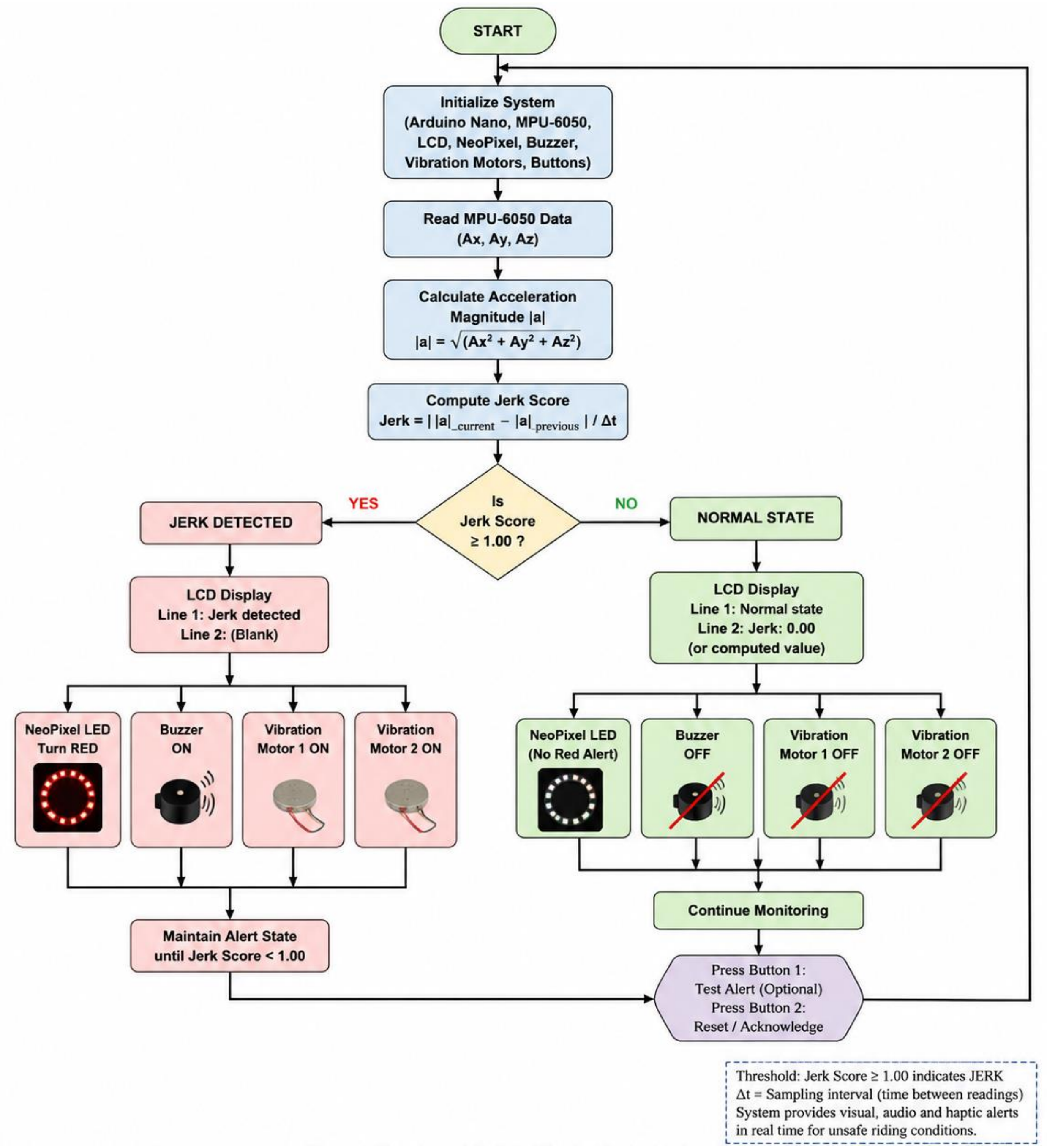

Figure 4:- Flow chart of Two wheeler monitoring system

The flow begins when the device powers on. The Arduino initializes the LCD, MPU-6050, NeoPixel LED, buzzer, and vibration motors. The system then repeatedly reads acceleration data, computes acceleration magnitude, computes jerk score, compares the jerk score with the threshold, and updates the output devices. If the threshold is crossed, warning outputs are activated; otherwise, the system remains in normal display mode.

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Table 1- Illustrative sample dataset for normal and jerk conditions

Time (s)	Jerk score	State label
0	0.05	Normal
1	0.08	Normal
2	0.06	Normal
3	0.1	Normal
4	0.07	Normal
4	0.35	Normal
5	1.2	JERK
6	1.55	JERK
7	0.78	Normal
8	0.31	Normal

Figure 5 shows the illustrative jerk score under normal riding. The jerk score remains below the threshold of 1.00, so the system remains in the normal state. The LCD would display "Normal state" and "Jerk: 0.00" or the computed value, while the buzzer and vibration motors remain inactive.

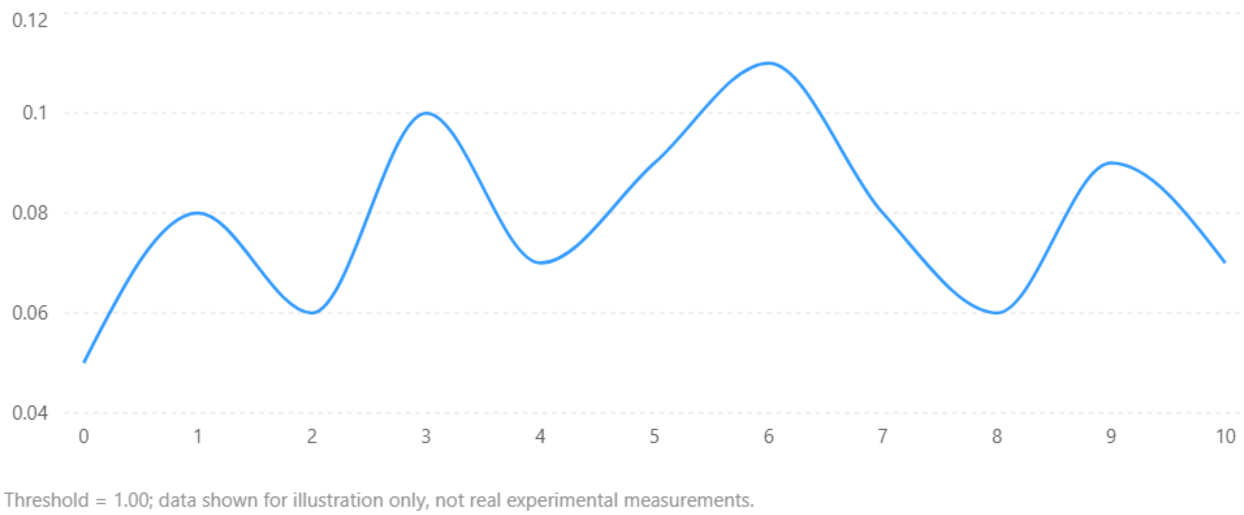

Figure 5. Sample normal riding jerk metric versus time. Synthetic/sample data only.

Figure 6:- Actual Image of Normal state

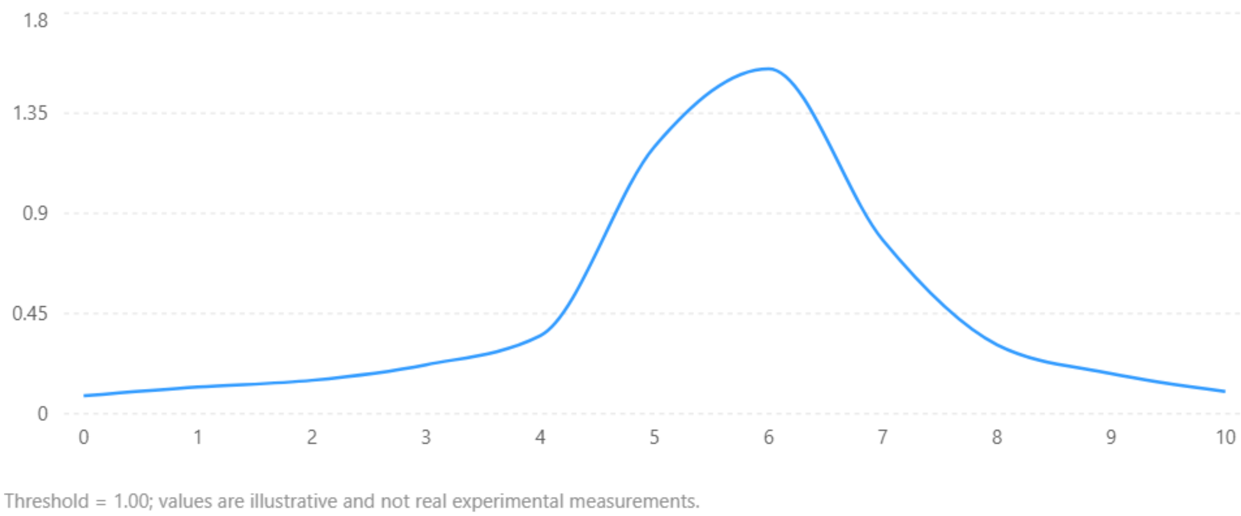

Figure 7. Sample Jerk/Unsafe Riding Metric versus Time

Sample jerk/unsafe riding metric versus time. Synthetic/sample data only. The jerk score crosses the threshold value of 1.00 at five s and six s, indicating a jerk condition. During these time points, the LCD displays “Jerk detected,” the NeoPixel LED turns red, the buzzer activates, and the vibration motors provide haptic feedback to the rider.

Figure 8 :- POC showing the sudden jerk state

6. Results and Discussion

The illustrative results show the expected behavior of the proposed threshold-based method. Under normal riding, the jerk score remains below 1.00 and no alert is activated. During the jerk condition, the metric crosses the threshold, causing the device to transition into the JERK state. This confirms the logical operation of the detection and alert algorithm.

The simplicity of the threshold method is suitable for Arduino Nano implementation. However, threshold-only systems may be sensitive to mounting orientation, engine vibration, road texture, and sensor noise. Therefore, real deployment requires calibration, filtering, and repeated testing on different roads and vehicles. A moving average filter, axis-specific thresholds, or adaptive baseline estimation could reduce false alerts. Future versions could also log data for offline analysis and integrate smartphone or IoT connectivity for ride-history visualization.

7. Conclusion and Future Work

This paper presented a complete design and methodology for a Two-Wheeler Monitoring System that detects sudden jerk conditions and alerts the rider in real time. The system uses an Arduino Nano, MPU-6050 accelerometer–gyroscope sensor, 16×2 I2C LCD, NeoPixel LED, buzzer, and two button-size vibration motors. The device is enclosed in a CAD-designed PLA 3D-printed case and mounted on the two-wheeler speedometer. A normalized jerk metric was defined from acceleration magnitude changes, and the given project threshold was interpreted as a jerk-score threshold of 1.00.

The proposed system demonstrates a practical low-cost embedded approach for rider safety feedback. Since real-world experimental data were not provided, the presented results are illustrative and should be treated as sample data only. Future work should include sensor calibration, real road testing, adaptive threshold selection, filtering, data logging, smartphone application integration, GPS tagging, IoT connectivity, and machine-learning-based classification of different unsafe riding events.

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