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Early Detection of Microsleep in Motorcycle Helmet Based on Pulse Sensor

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ABSTRACT

Microsleep can be defined as a brief condition in which someone unintentionally falls asleep for a few seconds to several minutes. This condition can occur in anyone and poses a high potential risk, especially when engaged in activities that require high concentration, such as driving. To detect and address the potential dangers of microsleep while driving, this research has designed a smart helmet capable of early detection of signs of microsleep and taking actions to awaken the rider. This system uses a pulse sensor connected to an Arduino and placed on the backside of the helmet. Detection of beats per minute (bpm) is crucial to determine whether the rider is drowsy or not. This is essential for providing early warnings to the rider. If the rider's bpm reading is <60, indicating drowsiness, the system activates a vibrator to shake the helmet. If this condition persists for more than 7 seconds, the speaker also activates to play music, which will only stop when the bpm reading is >60. Testing was conducted on 5 test subjects, with each subject undergoing 5 trial tests, resulting in a total of 25 test runs. The results indicate that the designed system is capable of reading microsleep conditions and activating the vibrator and music according to the configured settings.

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1. INTRODUCTION

Rest is one of the ways aimed at restoring the body's condition after engaging in activities. Rest is also one of the basic needs of humans because during rest, a person can rejuvenate and regain their vitality, which is essential for maintaining good health. This enables individuals to perform their daily activities effectively, and one of the ways to achieve this is through sleep [1].

Allocating the recommended amount of sleep is essential for maintaining overall health and well-being. However, not everyone optimally utilizes their sleep time, especially those with busy daily schedules. This can be particularly problematic for individuals who frequently travel long distances by vehicle, such as riding a motorcycle, and may lead to drowsiness.

Drowsiness while driving can significantly increase the risk of accidents, resulting in a higher number of road traffic accident victims [2]–[7]. Therefore, there is a need for early warning systems to detect the onset of microsleep, which is the precursor to drowsiness. Ideally, these warnings should directly stimulate the hypothalamus, causing the hypothalamic nerves to become active, thus reducing drowsiness. Drowsiness poses a danger to all motor vehicle users, especially those operating cars and motorcycles. Most research related to early drowsiness detection has been conducted for car drivers using various sensors, including biosensors and cameras. However, there have been limited innovations in the detection of microsleep among motorcycle riders, primarily due to constraints related to accessible areas for detecting microsleep in motorcycle riders.

Research studies related to drowsiness detection in drivers have utilized various bio signals and sensors. Studies have detected drowsiness based on eye blinks. Meanwhile, research [8]–[12] has used heart rate or electrocardiogram (EKG) to detect drowsiness in drivers. A combination of eye blink and EKG has also been employed to achieve optimal results in early drowsiness detection, as demonstrated by [13]. Brain signals can also be further analyzed to detect microsleep. Research on early drowsiness detection based on brain signals or electroencephalography (EEG) has been conducted by [14]–[18]. Most bio signals have been used to examine the occurrence of microsleep, but there is also research that incorporates changes in physical movements for detection, as seen in the study [19].

Eyeblink-based research typically uses a camera to capture images to assess the condition of the eyes. Studies [3], [4], and [6] have collected eye blink data, including both duration and frequency, to determine the level of drowsiness. On the other hand, studies [2], [5], and [7] have used eye movement tracking to determine if someone is drowsy or not. Eye tracking employs methods like the Haar Cascade Classifier to detect whether the eyes are open or closed. Drowsiness is classified when the eyes are considered closed. Early drowsiness detection using cameras can be influenced by the quality of camera capture. Data processing accuracy can be compromised due to inadequate lighting or excessive head movement that may go undetected by the camera. Additionally, substantial computation is required to achieve optimal classification results.

Research based on EKG signals has also been widely used to detect drowsiness. Some studies use the variable of beats per minute (bpm) [9]-[12], while study [8] not only calculates bpm but also examines heart rate variability (HRV) to detect and predict microsleep events. The use of EKG bio signals makes microsleep detection relatively straightforward. A simple pulse sensor device can provide information on bpm values, indicating the presence of drowsiness in drivers. According to the National Institute of Health (NIH), the normal resting heart rate varies significantly with age. Table 1 shows normal heart rate values based on age [12]. From the table, it is apparent that the normal heart rate threshold for individuals above the age of 10 is 60 bpm. Thus, the resting heart rate or calm state classified as drowsy falls below 60 bpm. Assuming that drivers are 17 years old or older, bpm values below 60 are considered to indicate a calm and drowsy state.

Table 1. Heart rate during ordinary activity by age range

No.	Age	Heart Rate (bpm)
1	1 month	70 – 90
2	1-12 month	80 – 160
3	1-2 years	80 - 130
4	3-4 years	80 - 120
5	5-6 years	75 - 115
6	7-9 years	70 – 110
7	>10 years	60-100

The study [13] combines the detection of eye blinks with measuring bpm values. Both of these variables are considered crucial characteristics for assessing the level of drowsiness in drivers. This research produced a range of bpm values between 55-70 for 8 test subjects with an age range of 15-58 years. The average bpm during drowsiness was 63.63.

In addition to using eyeblinks and EKG, another parameter used to determine drowsy states is electroencephalograph (EEG) signals, also known as brain signals. Studies [15]-[19] analyze EEG signals to assess an individual's drowsiness level. The use of EEG signal parameters generally involves image processing methods to classify each signal pattern in the brain as drowsy or not. This process typically requires a substantial amount of data and lengthy iterations, making it computationally intensive and memory-consuming.

Furthermore, to capture EEG signals, electrode sensors need to be placed at various points on the head, which can sometimes be uncomfortable for the driver.

Another sensor used to detect drowsiness is the accelerometer, as employed in the study [19]. This research uses changes in head movement along the x, y, and z axes as an indication of drowsiness. Although the installation of sensors on the head is referred to as "wearable" for drivers, the accuracy of this system is only 70%. There is a possibility that head movements not related to drowsiness may still be interpreted as drowsy conditions. In reality, head movements can occur for various reasons other than drowsiness.

From the aforementioned research, studies related to early drowsiness detection for motorcycle riders include [8], [10], and [12]. Research [8] uses eye blinks to detect drowsiness and activates the motorcycle seat's vibration to alleviate drowsiness. Meanwhile, study [10] employs a pulse sensor as an indicator of drowsiness and uses helmet vibrations to combat drowsiness. Research [12] has also implemented vibrations and sounds in motorcycle helmets. However, the output from the pulse sensor used in this study was not satisfactory, with significant noise that affected bpm readings. Additionally, bpm readings from this study were not compared to more standard measuring instruments.

Based on the previously mentioned studies, this research designed a microsleep detection device for motorcycle users using a pulse sensor attached to the helmet strap in the area that contacts the neck's pulse point. A vibrator and a mini speaker that plays music were added as warning alarms for motorcyclists. The BPM parameter was utilized for early detection of microsleep in riders using a threshold reference from [12]. When a rider's BPM falls below 60, the vibrator activates, and if the rider's BPM remains below 60 for 7 seconds, the mini speaker emits sound, which stops when the BPM returns to >60. The bpm values from the previous device will be validated using more standardized reference instruments.

2. METHOD

2.1 Block Diagram

The block diagram of the Early Microsleep Detection System for Motorcycle Users Based on the Pulse Sensor is shown in Figure 1.

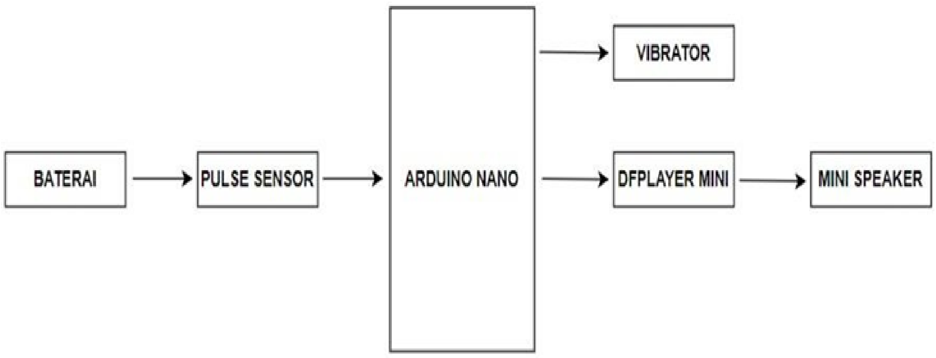

Figure 1. System Block Diagram

In this system, there are several components, including a battery, a pulse sensor, an Arduino Nano, a vibrator, a DFPlayer Mini, and a mini speaker. In this system, the battery serves as the voltage source. The pulse sensor is used to read the bpm, which is then processed by the Arduino. After processing the data from the pulse sensor, the Arduino triggers the vibrator and the DFPlayer Mini to produce outputs. The vibrator vibrates in accordance with the readings from the pulse sensor, as specified. Additionally, the DFPlayer Mini generates an audio signal that is played through the mini speaker, producing sound as specified.

2.2 Flowchart System

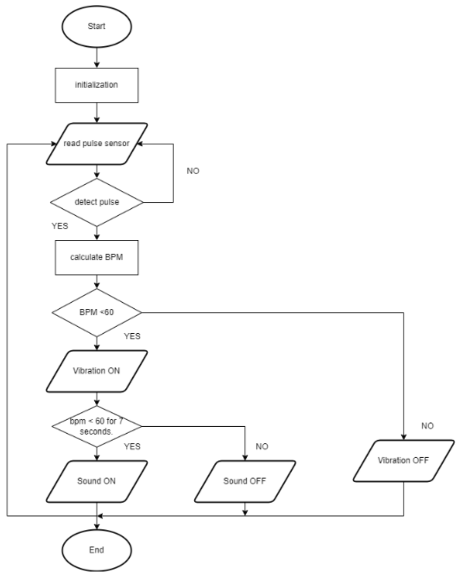

Figure 2. Flowchart System

Figure 2 is the flowchart of the early microsleep detection system for motorcycle users based on the pulse sensor and BPM calculation. From the flowchart above, it can be observed that when the pulse sensor begins reading, it calculates the bpm. If the pulse sensor doesn't detect bpm, it will repeat the detection process. If the pulse sensor reads a bpm value of <60, the vibrator will activate for 7 seconds. If the bpm condition returns to >60, the vibrator will turn off, and the pulse sensor will resume the detection process. However, if the vibrator has been active for 7 seconds and the bpm remains <60, the speaker will activate and play high-beat music until the bpm returns to >60.

2.3 Mechanical Design.

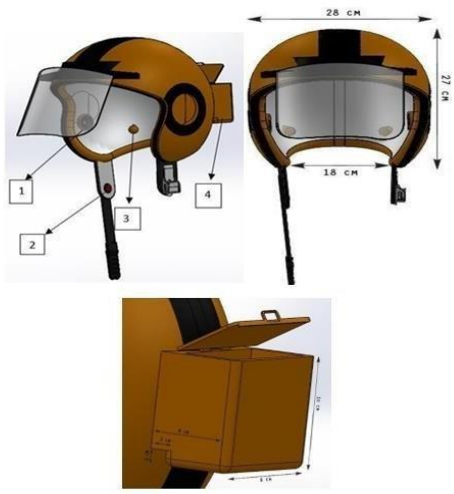

Figure 3. Mechanical Design

Description of Figure 3:

1. Mini Speaker.
   The mini speaker is a small portable audio device capable of converting electrical signals into sound frequencies by causing vibrations in the diaphragm. This mini speaker serves to help maximize the sound output generated by the sensor data to effectively wake up the motorcycle rider when drowsy.
2. Pulse Sensor.
   The pulse sensor is used to convey information to a device that can determine the rider's heart rate per

minute (BPM) to detect if microsleep is occurring.

3. Vibrator.
   The motor vibrator is an electromagnetic device capable of converting electrical energy into mechanical energy. The use of the vibrator is to maximize the device's effectiveness in quickly waking up the rider if they become drowsy.
4. Box
   The box is used to house the components such as Arduino, battery, and DFPlayer Mini. It will be placed at the rear of the helmet with a size that has been adjusted accordingly.

2.4 Electronic Circuit Design.

The Figure 4 displays the electronic circuit wiring of the Early Microsleep Detection System for Motorcycle Users Based on the Pulse Sensor.

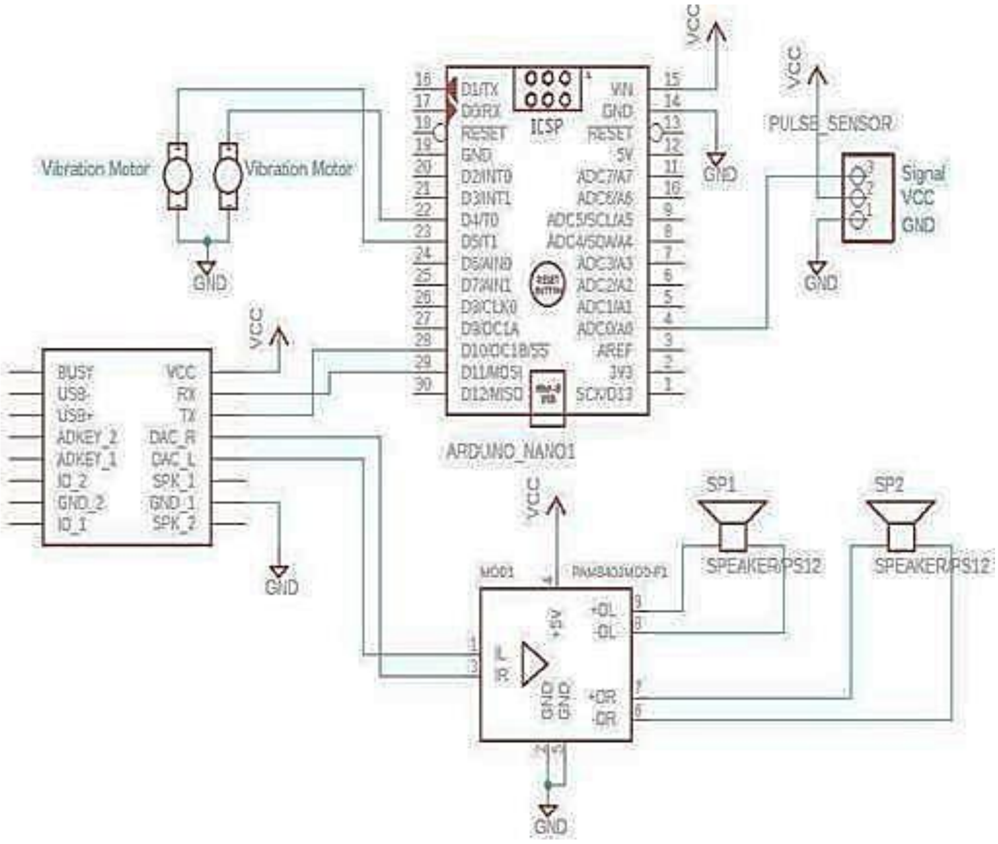

Figure 4. Electronic Circuit Design

3. RESULTS AND DISCUSSIONS

3.1 Pulse Sensor Test

The testing of the pulse sensor was conducted to determine whether the heartbeat sensor is functioning correctly. Figure 5 shows the readings from the pulse sensor connected to analog pin 0 of the Arduino. The test results indicate that the sensor is working well, as evident from the matching shape of the generated signal.

From the signal waveform of the pulse sensor, we can obtain the BPM value by establishing a threshold point on the signal. When the ADC signal exceeds the specified threshold value, it counts as one beat or one pulse. The determination of the threshold value is based on the sensor's output signal as displayed on the signal plotter when the sensor detects a pulse, as well as the results of comparison testing with BPM values obtained using a digital OMRON blood pressure monitor.

During testing, if the number of BPM on the device is lower than the number of BPM on the OMRON, the adjustment made is to reduce the threshold value. This adjustment is necessary because a threshold that is set too high can lead to some beats not being counted since they have ADC values lower than the threshold. In this research, the threshold value was set at 550. To obtain BPM, the calculation process is conducted over one minute. During this one-minute interval, the number of beats that successfully surpass the specified threshold value is counted and becomes the BPM value.

Figure 6 shows the readings of the BPM values displayed on the device, while Table 2 provides a comparison between the BPM values on the device and the results measured by the digital OMRON blood pressure monitor. The average percentage error in BPM values from the testing is 2.18%, indicating that the BPM results from the device have an accuracy of 97.28%.

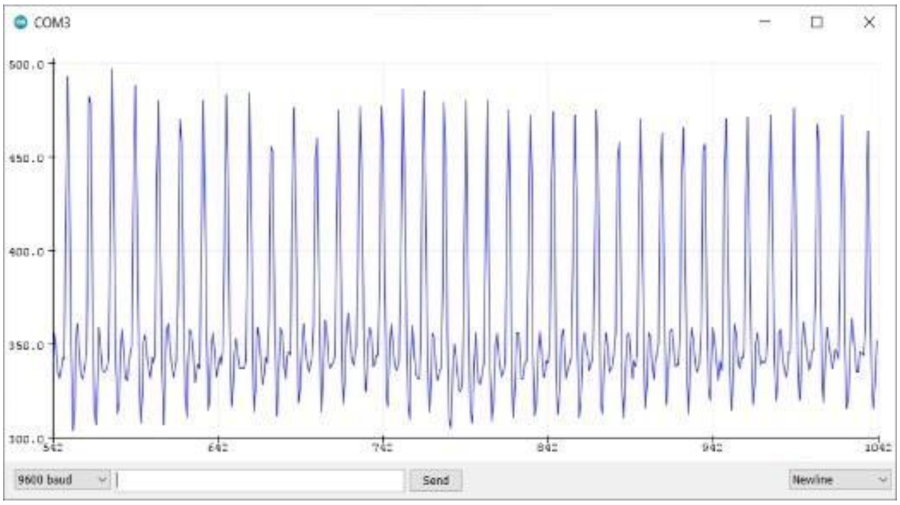

Figure 5. Pulse Sensor Testing

Figure 6. Display of BPM Values on the Device (Helmet)

Table 2. Comparison of BPM Values on the Device with Digital OMRON Blood Pressure Monitor

Test	Pulse Sensor (bpm)	OMRON Tensimeter (bpm)	Error (%)
1	96	95	1.05
2	98	95	3.15
3	96	99	3.03
4	94	97	3.09
5	93	96	3.12
6	94	94	0
7	93	91	2.19
8	94	94	0
9	100	95	5.26
10	103	102	0.98
Average Error			2.18

3.2 System Test

The testing was conducted on 5 male subjects, with data collected from each subject 5 times. The testing was divided into two conditions: normal condition and drowsy condition. Table 3 shows the results of the testing under normal conditions, where the test subjects were asked to remain calm and not engage in activities such as moving, talking, and so on. This was done because the sensor placed on the chin area and attached to the helmet strap is highly influenced by the movement of the surrounding area.

Table 3. Test Results Under Normal BPM Condition

Test Subject	Age (Year)	Gender	Heart Rate Range in 5 Testings (BPM)	Condition	Vibrator	DF Mini Player
Subject 1	21	Male	73-77	Awake	OFF	OFF
Subject 2	21	Male	74-82	Awake	OFF	OFF
Subject 3	21	Male	76-81	Awake	OFF	OFF
Subject 4	21	Male	78-86	Awake	OFF	OFF
Subject 5	20	Male	68-73	Awake	OFF	OFF

From Table 3, it is evident that the range of BPM values is 68-86, indicating a normal condition or not being drowsy. Therefore, in this test, both the vibrator and the DFPlayer remain in the off state. Proper sensor placement during the testing also affects the reading results. Incorrect placement can result in BPM readings not appearing on the monitor screen.

Table 3 shows the test results for BPM values during the considered drowsy condition. The testing was carried out on the same subjects at night. Data was collected when the subjects felt drowsy. Data collection started 5 minutes after sensor placement to ensure the subjects were more relaxed and BPM values began to decrease. The data collection lasted for 1 minute to obtain the BPM range. Other data collected in addition to BPM included the time when the BPM value dropped below 60 to ensure that the DFPlayer turned on at the time specified in the program, which is 7 seconds.

Tabel 3. Test Results When Drowsy

Test Subject	Age (Year)	Gender	Heart Rate Range in 5 Testings (BPM)	Time (s)	Condition	Vibrator	DF Mini Player
Subject 1	21	Male	54-56	< 7	Drowsy	ON	OFF
Subject 2	21	Male	55-62	< 7	Drowsy	ON	OFF
Subject 3	21	Male	57-59	> 7	Drowsy	ON	ON
Subject 4	21	Male	53-57	< 7	Drowsy	ON	OFF
Subject 5	20	Male	53-60	< 7	Drowsy	ON	OFF

In Table 3, it can be observed that the BPM values during data collection in the drowsy condition fall within the range of 53-62. Some of the data in this range indicate BPM values above 60, as it's possible that the subjects may have required more than 5 minutes after the device was installed to reach a fully drowsy state. The table also shows that the vibrator is activated when BPM falls within this range. Meanwhile, the DF Mini Player only turns on when the BPM value remains below 60 for more than 7 seconds, which occurred for Subject 3.

From the conducted testing, it is evident that the system has performed as planned. Challenges during data collection include ensuring that the sensor is correctly positioned to prevent BPM values from not appearing. Additionally, the test subjects must be conditioned not to move or talk, especially in the facial area, as the sensor is placed on the lower part of the chin.

4. CONCLUSION

From the results of the testing, the device has functioned according to the design, where when BPM is <60, the vibrator will vibrate, and if the BPM remains <60 for 7 seconds, the DFPlayer Mini will send a command to the speaker to play music. If the BPM is >60, both the vibrator and speaker will stop working, indicating that the BPM has returned to a normal condition. Improvements in sensor selection or placement are needed to enhance the accuracy of BPM data collection.

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