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Drowsiness Detection System: A Technological Approach for Accident Prevention in Mining

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ABSTRACT

In recent years, driver's drowsiness has been identified as the leading causes of road accidents. It is crucial to prevent such accidents, especially in the mining sector, where they can lead to multiple fatalities, serious physical injuries, and significant economic losses. Various sleepiness detection systems exist, but they are not properly implemented due to their high cost and complex design. Therefore, an alternative system that can recognize early signs of sleepiness and alert the driver is required. This paper presents a prototype of a drowsiness detection system using an IR sensor, which can be used to detect the time period forclosure of the driver's eyelids. TheGoggles are attached with theIR sensor to identify the drowsiness. After development and performance evaluation of proposed model, the results conclude that using an IR sensor as an eye blink sensor to determine the driver's level of drowsiness is feasible with an accuracy rate of 84% after testing. It also provides improved portability and cost-effectiveness.

KEYWORDS: *Drowsiness detection, IR sensor, Arduino, Mine Accidents, Alerting system.*

I. INTRODUCTION

Drowsiness driving is the most common cause of road accidents worldwide, resulting in more crashes each year than speeding, drunk driving, and other major accident causes combined. According to the National Safety Council (NSE) United States, drowsy driving causes approximately 100,000 crashes, 71000 injuries, and 1550 fatalities each year [1]. According to DGMS Technical Circular No. 03 of 2013, an analysis of fatal accident statistics in coal mines from 2006 to 2011 revealed that out of 135 accidents in opencast mines, 58 were caused by dumpers, 59 by tipper trucks, and 18 by other vehicles. All of these are vehicle-related accidents, with the majority of them caused by driver distraction. Drowsiness in drivers can occur as a result of long work hours and poor sleep habits. It is especially dangerous in the mining industry, where human error can lead to significant material damage and human injury [2]. According to one survey, drowsy driving accounts for nearly 40% of all road accidents [3]. So, many innovative systems are designed using various methodologies to eliminate such mining accidents, prevent them from occurring, and alert drivers. Drowsiness has been monitored using various methods, such as vehicle-based measures, behavioral measures, physiological measures, and questionnaire-based subjective measures, all of which were developed by researchers [4]. Using a camera, the behavioral measures detect any drowsiness symptoms (yawning, eye closure, eye blinking, head position, etc.) and alert the driver if any of these symptoms occur [5]. The majority of published studies in the literature focused on determining drowsiness using eye blinking or a percentage of eyelid closure [5-7]. Dinges et al. [8] validated the latter approach for drowsy detection. It was also regarded as one of the best potential ocular measures for assessing fatigue [9]. Many manufacturers have installed systems in their vehicles that can be used with the help of cameras for real-time monitoring in various industries. However, detecting drowsiness with a camera-based approach has a limitation in terms of illumination, as standard cameras do not work effectively at night when monitoring is more important [8, 10]. Bergasa et al. [5]developed a system that uses a charge-coupled device (CCD) micro camera sensitive to near IR to overcome this limitation. Despite the fact that the IR camera improved night-time performance, it is considered less robust during the day due to the sun's rays interfering with IR reflections [9]. Other concerns for camera-based systems include high costs and image loss. Furthermore, to extract drowsy symptoms, most of these systems require computers, image processing algorithms, and feature extraction techniques. So, using an IR sensor is one of the most appropriate ways where it is both effective and feasible. It is low-cost sensor that can be used to detect eye blink. The infrared light will reflect into the surface of the eye using an IR sensor, detecting eyelid movement. The IR Sensor is non-invasive and safe for the eyes. It transmits invisible light signals in front of the naked eye [11]. A person's normal eye blink frequency ranges from 12 to 19 per minute, so eye blink frequency below this range is considered drowsy [12]. Thus, the normal active eye blink interval ranges from 2 to 10 seconds [13]. As a result, the eye blink interval greater than 10 seconds is inactive.

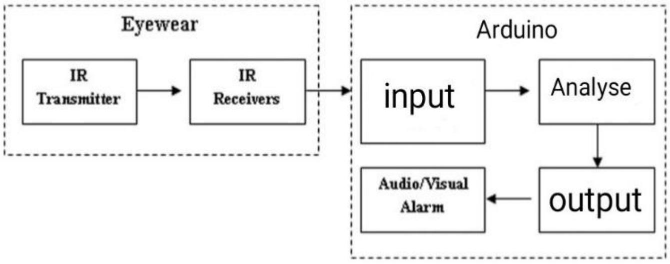
The NHTSA (National Highway Traffic Safety Administration) study, on the other hand, proposed that 80% of collisions occur in just 3 seconds of distraction [14]. Furthermore, another study found that if a person's eyes are not focused on the road for 2 seconds or longer, it can lead to an accident [15]. Using buzzer is the best method for alerting someone. The sound of a buzzer can wake a driver who has fallen asleep. [13]. So, the piezoelectric buzzer, can be used as an alarm because it emits an audible alarm. [13].

The main factors which are very much important in mining industry are safety and feasibility. So, to compromise both the factors with optimum safety and feasibility a better prototype is required with respect to current technologies. Most of the existing systems consist of a camera mounted in front of the driver. It detects the driver's face and eyes to determine whether or not he is drowsy. However, when facing the driver, it blocks the driver's frontal view. As a result, it may create other difficulties while driving. So, this method had this disadvantage. Furthermore, it displays different results depending on the position of the eye. When the eye is in the uplink position, the result is 80% accurate, while in the downlink position, the result is 55% accurate. According to the manufacturer, the CV (Computer Vision) detects only 40% of the driver's face and fails in an oblique position [16,17].Also, by studying various detection systems for drowsiness from the literature, it is clear that portable detection models will be more helpful for implementation in the mining industry because of their high portability. These existing systems may be affected by environmental factors like lighting conditions, weather conditions, and vehicle vibrations, which can impact the accuracy of the detection. The placement of sensors in existing systems may be limited to specific locations on the driver's face or body, which could limit the types of data that can be collected and analyzed. Existing systems may require significant calibration and setup time, which could be inconvenient for drivers. The algorithms used in existing systems may be relatively simple and not as sophisticated as those used in latest technologies. Existing systems may rely on a single type of detection (e.g., eye blinks or head movements), which could limit their overall effectiveness [2], [18], and [10]. So, it is very much important to develop a portable, efficient, and cost-effective system to deal with the limitations of expensive and complicated systems.

This paper proposes a user-friendly drowsiness monitoring device that works on IR sensor-based detection to prevent mining accidents caused by drowsiness by overcoming limitations in other technologies [2], [18], and [10]. The proposed system is based on "Eye Lid Closure Detection", which works with the help of infrared sensors. This system works by directing an infrared beam to the human eye via IR emitters mounted on the driver's glasses. When the eye is opened, the IR light ray directed to the eye is absorbed, while the majority is reflected and collected by IR receivers mounted on the same eyewear. When the eye is closed, most of the IR radiation is reflected and received by the IR receivers, which convert it to a voltage proportionate to the open or closed state of the eye. Thus, these signals can be used to provide an audio alarm to the driver if eye closure exceeds a certain time limit. The frequency of eye closures greater than 1 s and the number of time-to-line crossings less than 0.5 s were the best predictors of poor driving. The purpose of this research is on eye detection using an eye blink sensor. It detects drowsiness in a person's eye blinking while driving. The eye blink sensor detects the blinking of a driver's eye. Normal eye intervals range from 2 to 10 seconds. As a result, eye lids closure for more than 2 seconds between blinks indicates drowsiness. This causes the microcontroller to send data to the buzzer, alarming and alerting the driver. As a result, the device's alarm system will use the sense of hearing of driver to alert him. The device can only detect the number of seconds a person's eye is closed. It cannot detect a person's breathing or sigh, heart palpitations, or body position. Furthermore, detection may be limited to the person wearing the eye blink sensor. The performance of the developed model will be evaluated with the help of a confusion matrix.

The confusion matrix is a widely used performance evaluation tool in machine learning and statistical analysis. It is used to evaluate the performance of a classification algorithm by comparing the actual and predicted values of a target variable. A confusion matrix is a table that summarizes the performance of a classification model by comparing actual values with predicted values. It is a square matrix with the same number of rows and columns as the number of classes in the data. The diagonal elements of the confusion matrix represent the correctly classified instances, while the off-diagonal elements represent the misclassified instances. The main metrics used to evaluate a classification model using the confusion matrix for this particular model in the performance evaluation are Sensitivity, Specificity, Accuracy, Error Rate, and Precision.

- Sensitivity: Measures how much effectively the system detects actual cases of drowsiness.
- Specificity: Measures how much effectively the system identifies non-drowsy individuals.
- Accuracy: Measures how often the system correctly classifies both drowsy and non-drowsy individuals.
- Error Rate: Measures how often the system makes classification errors.
- Precision: Measures how often the system correctly identifies true positives among all cases classified as positive.



These metrics are important for evaluating the effectiveness of a drowsiness detection system and identifying areas for improvement. In comparison to various existing systems and limitations in [2], [18], [10], the IR sensor-based system may offer advantages such as:

- More flexibility in sensor placement could enable the collection of a wider range of data.
- A simpler setup and calibration process could be more convenient for drivers.
- More accurate and reliable detection in various environmental conditions, including low light.
- More sophisticated algorithms for processing sensor data could improve the overall accuracy and effectiveness of the system.

II. METHODOLOGY

A. Proposed system

In this paper, IR sensor-based drowsiness detection system is proposedthat is intended to overcome the drawbacks of the existing system. This will become the most optimum model related to the mining industry with respect to safety and feasibility. This system warns the driver if he or she is drowsy or tired. The proposed system's hardware components consist of two major units: an eyewear unit and a processing unit. The eyewear unit consists of an IR Sensor Module (LM393 Photoelectric Sensor) with an IR transmitter and IR receiver fixed to transparent goggles. The processing unit consists of components like an Arduino Nano v3 microcontroller, a 3.7V 500mAH Li-Po rechargeable battery, a micro switch, and a piezoelectric buzzer (an audio alarm).

B. ConceptualFramework

The conceptual framework of this study can be observed in figure 1. The state of eyes (open/closed) is the input to the system. The Arduino Nano microcontroller will analyze, interpret and process if the person is in a normal or drowsy state with the help of prefixed time levels. If the person is in a drowsy state, the buzzer will execute its intended functions as an alerting system.

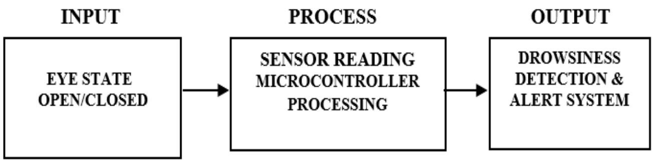


Figure 1: The Conceptual Framework

C. System BlockDiagram

As reflected in figure 2, the eye blink sensor detects the state of the eyes. The microcontroller which is Arduino nano will process if the collected data from the IR sensor are in a normal state or drowsy state.The Arduino takes input from the eyewear system then it interprets, analyzes, and processes with prefixed calibrations. The relay is connected between the Arduino and the alarm which is the buzzer. If the device needs to alarm, through a relay, the buzzer will take its course. The 3.7 battery was utilized as the power source for the system. The buzzer will continue in operation until the eyes return to a normal state.

Figure 2: Functional Block Diagram

D. HardwareDevelopment

The proposed system should be portable and more compatible than other systems. So, the IR sensor module (LM393 Photoelectric Sensor) is attached to a safety transparent goggle. The photodiode and the phototransistor were fixed at the upper left corner of the safety goggles. The Arduino Nano board along with 3.7V 500mAH Li-Po rechargeable battery, a micro switch, and a piezoelectric buzzer is attached to the side of the goggles. All the connections are given by jumper

wires and are properly soldered into the eyewear.

The IR Sensor was used as an eye blink sensor, capable of detecting eye blinking. Its module consists of both a photodiode and a phototransistor. An IR signal can be generated by the photodiode. The photodiode sends infrared rays to the driver's eye, while the phototransistor receives thereflected signal from the eyeball.

Figure 3: Flowsheet for the IR detection system.

As a result, the IR should be placed near the glass, where it can reach the eyeball. The IR sensor is mounted on the goggles. The sensor can be triggered whenever there is an eye movement that analyzes as a blink. The eye blink sensor produces no output when the eye is closed. However, if the eye is closed, the eye blink sensor will send a signal to the Arduino.

E. SoftwareDevelopment

TheArduino Nano is a microcontroller that can be programmed. The Arduino is being programmed in this study to detect drowsiness in the driver. Figure 3 depicts the flow sheet. The eye blink sensor will first detect the state of the eye as well as the number of seconds that the eyes are closed. The microcontroller will use it to determine whether the collected eye blink detection is normal or drowsy. A normal state means the driver's eyes are open and blinking every 2 seconds. If this happens, the Arduino will simply restart the loop and take no action. on the other hand, the drowsy state is indicated by the driver's abnormal blinking rate. If the driver closes his eyes for 2-3 seconds, the Arduino will send a signal to the buzzer, causing it to function. As a result, the Arduino will send a triggering signal to the buzzer until the eyes are open. The Arduino Nano was calibrated and programmed in the Arduino IDE (Integrated Development Environment) software to read input and trigger output in accordance with the IR sensor.

F. Final PrototypeDesign

The final prototype design is observed in figure 4. As shown in the figure, it is comprised of an eyewear unit (with eyeglasses and IR sensor module) and a processing unit (with Arduino Nano, Battery, and buzzer). The IR sensor is attached to the upper right corner of the safety goggles. The gogglesare transparent, lightweight, and compatible. All the connections are connected by jumper wires and properly soldered.

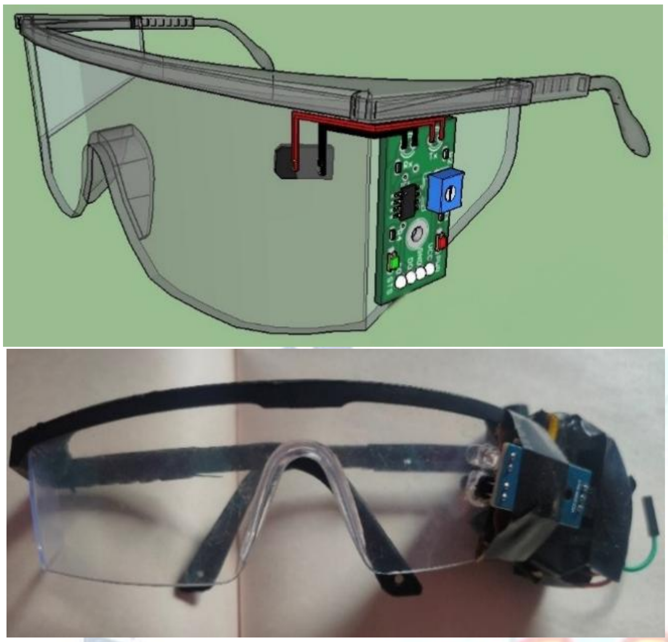


Figure 4: Actual Model

III. RESULTS

A.Function test procedures

To determine if the device is functional, it must be tested. To achieve the best range of detecting eye blinks, the eye blink sensor should be calibrated first. The trim pot/distance adjuster located on the IR sensor module is used to adjust the sensitivity of the IR sensor. After providing Arduino nano code, the sensor module was tested. The system was tested with obstructions placed in front of the IR sensor to ensure that the entire system worked properly. The processing time for the system to analyze and activate the buzzer is measured.

B.FunctionalityTests

To test the proposed model in terms of its functionality and accuracy, the model is tested 10 times under a simulated environment. If the driver had closed his eyes for 2-3 seconds, it means the driver is in a drowsy state. In this case, the person pretends to be a drowsy driver which means he pretends to close his eyes for various time intervals. Based on the test, if the person is in a normal state with an eye blink time of fewer than 2 seconds, the buzzer will not cause an alarm. The person also tests the device by letting the driver close his eyes for 2-3 seconds 5 out of 10 times, buzzer activated within a second. For a rapid eye blink rate of less than 1 second of blink interval, the Arduino nano is not able to process in a compatible manner, thus the buzzer is triggered 3 times in 10 tests with rapid blinking, whereas the buzzer is not activated for 2 times. So, overall, it functions 7 out of 10 times being tested accurately including with rapid blink rates.

It also tested the normal state of the model. The normal state is when the driver is not drowsy indicating without any alarm. To know if it is normal, the person's eyelids closure must be within 2 seconds. Thus, the blink interval has to be in between 2-10 seconds. After a couple of minutes, in just normal blinking, the device did not take any actions indicating that the person is not drowsy. It also tested 5 times with a slow blink rate of 19 blinks in a minute with blink intervals of less than 2 seconds but the buzzer is not activated. Another one had tested the normal state by 10 times, the device works at a normal state 8 times within a second, but it delayed half a second 2 times to trigger. This indicates the face shape and distance between the sensor with eyes are also key for the effective working of the sensor. It is observed in the actual model in figure 7.

C. Accuracy of the Device Using ConfusionMatrix

The model is tested on 5 different persons with overall 100 trials to determine the device's performance (50 normal states, 50 drowsy states). Table 1 shows the confusion matrix with predicted observations as 100 for 100 trials because they are taken with 100% accuracy and functionality in prediction. As shown in Table 1, the confusion matrix that records various observations of the device [18]. A confusion matrix is a table that summarizes the performance of a classification model by comparing the actual and predicted labels for a set of test data. For drowsiness detection, the confusion matrix can show the number of true positives (correctly identified drowsy instances), true negatives (correctly identified non-drowsy instances), false positives (non-drowsy instances incorrectly identified as drowsy), and false negatives (drowsy instances incorrectly identified as non-drowsy).

Based on the confusion matrix, several performance metrics can be calculated, such as accuracy, precision, sensitivity, specificity, and error rate, to assess the effectiveness of the drowsiness detection model.

It is predicted that in a normal state, there will be 50 normal states in the actual test, and in a drowsy state, there will be 50 drowsy states. The predicted normal state is referred to as predicted positive in the confusion matrix tool, while the predicted drowsy state is referred to as predicted negative. In terms of reality, the normal state is referred to as a true positive, while the drowsy state is referred to as a true negative.

Table 1 shows that the device was identified 40 times out of 50 tests predicted to be normal. Whereas 10 times, when it is predicted to be normal, but in actual case, under rapid blinking rate, the buzzer triggers as if a person is drowsy even though they are not. So, it misidentified the normal state as a drowsy state 10 times.

Table 1: ConfusionMatrix

On the other hand, out of 50 tests predicted to be in a drowsy state, the device worked properly and alerted the driver that the driver was drowsy 44 times. Whereas 6 times, the device identified the drowsiness state as a normal state, even when it's predicted to be drowsy, the device did not provide an immediate system response to the driver in this case due to the rapid blinking rate.

	ACTUAL OBSERVATIONS	
PREDICTED OBSERVATIOS (100)	**Normal State**	**Drowsy State**
Normal State (50)	**40**	**10**
Drowsy State (50)	**6**	**44**

As shown in Table 1, out of 50 times predicted to be at normal state, there are 40 times that the actual device was identified correctly. And out of 50 times predicted to be a drowsy state, there are 44 times the device identified drowsiness correctly. The various performance metrics are evaluated with the formulae of a confusion matrix. The results of the confusion matrix in Table 1 show the values that will be helpful to calculate the sensitivity, specificity, accuracy, error rate, and precision of the device. The results have been calculated and are shown in the Table.

Table 2: Measure of Values

Measure	Value
Sensitivity	86.95%
Specificity	81.48%
Accuracy	84.00%
Error Rate	16.00%
Precision	80.00%

IV. DISCUSSIONS

Drowsiness is a serious problem that affects millions of people around the world, especially when driving, operating heavy machinery, or performing other critical tasks. In this study, a non-invasive drowsiness detection system based on an infrared (IR) sensor attached to wearable spectacles is proposed to detect drowsiness in real time by monitoring the eye blink rate and the duration of eyelids closure. The proposed system achieved 84% accuracy and alerted the user in real-time when their drowsiness level exceeded a certain threshold. The system's benefits include its non-invasive nature, ease of use, and portability. However, the system's limitations, such as its reliance on IR sensor accuracy and a lack of consideration for other factors that can influence drowsiness, must be addressed in future research. To improve the effectiveness of the drowsiness detection system using IR sensors fixed in transparent goggles, several recommendations can be made. These include addressing the limitations of this system by developing it to work with drivers who have different eye conditions or to work under extreme weather conditions, integrating it with other driver assistance systems, validating it through large-scale testing, and improving its user-friendliness and engagement.

V. CONCLUSION

This prototype is calibrated and positioned in such a way that it can detect signals from time period of eyelids closure at various stages. The IR sensor was powered by a 3.7-volt battery. When in operation, it can detect voltage changes proportional to eye movement. This voltage change will be analyzed by the Arduino Nano v3.0 microcontroller, which will compare the recorded values with the standard values provided to it by coding during the calibration stage. After comparing values in Arduino, the deviations will be used to provide an output to various systems; in this case, an audio alarm with a buzzer was used to alert the driver. As a result, the driver will be alerted, and an accident will be avoided. When the eyelid is opened, it will observe a constant voltage proportion. There will be voltage reading deviations whenever the eyelid is closed. The entire system was successfully tested and analyzed.

Based on the tests conducted, it shows that the prototype which uses an IR sensor as an eye blink sensor has good accuracy with high sensitivity to determine if the person is in a drowsy state or not for as long as it is properly attached to a fixed location of the goggles. With the help of buzzer, the driver is being facilitated by the system to be awake while driving. The results of the experiment show that the proposed system can distinguish between open and closed eyes and can trigger an alarmin the event of prolonged eyelid closure. With this proposed system, the study achieves good results for the detection and analysis of prolonged eyelids closure. It has the potential to become a universal technique for saving human lives in the future.

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