RAKSHAK - An energy efficient intelligent helmet

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***Abstract*—Wearable technology is gaining popularity, being employed in a variety of applications, and wearable safety devices have found high demand in the market as of late. This project work relates to an important area of application for wearable devices, which is road safety. The roads of developing and under-developed countries tend to be largely unsafe and vulnerable to accidents especially for two wheeler users. Apart from the riders own safety, the chaotic environment in roads and highways in such countries also poses safety concerns for the public which is often overlooked. Another key issue with the use of wearable devices is minimizing electronic waste. As environmental issues are a growing concern, it is crucial to use energy efficient methods wherever possible in developing technology. Our proposed device RAKSHAK (meaning 'protector' in Hindi) is a secure riding helmet that strives to strike an immaculate balance between incorporating several novel and thoughtful intelligent features involving Machine Learning and the Internet of Things for safety and convenience, as well as taking an environment friendly approach to consumer electronics by using a renewable energy source.**

***Index Terms*—Energy fficient embedded systems, Internet of Things, Machine Learning, Wearable devices, Road Safety**

I. Introduction

The populated two wheeler dominant countries like India , which is home to the worlds largest number of motorized two wheelers, poses an array of problems that are crucial to be solved with the development and ease of access to modern day technology. With minimum awareness and maximum exposure, two wheeler riders in the chaotic roads of the Indian subcontinent are vulnerable to accidents and increasingly so, as the population grows. Per vehicle mile traveled, motorcyclists are about 30 times more likely than a passenger in a car to die in a crash. And, more than half of motorcycle fatalities in 2013 were unhelmeted riders [1]. In 2020 alone over 1.5 lakh two wheeler accidents occurred in India causing about 56000 deaths in the country. This clearly suggests that Indian roads present a depressing scenario and most of these people who lost their lives were aged between 15 and 34 years according to the road accidents report in 2014. The report also reveals that the age group of 15 to 34 years accounted for 53.8 % of total road accidents [2]. The rise in population also comes with rise in energy consumption making it vital to employ sustainable, energy efficient approaches wherever possible. The key motivation behind pursuing the research work for embedded wearable electronics and Internet of things was to strike a balance between incorporating a number of intelligent features for purposeful applications as well as using an eco-friendly approach. With the growing consumer market of Internet of Things (IoT), interconnected devices have a huge potential in replacing and introducing some essential electronic devices in the wearable domain. Incorporating solar energy source and storage, and integrating sensors such as rain sensors and smoke detection sensors among others, the device covers a wide range of problem statements and scenarios that tackles a variety of issues including air pollution, visibility, drink and drive, traffic congestion, women safety, accident prevention and awareness of road signs, therefore significantly minimizing risk factors and contributing to overall road safety. The following sections depict the design and development of the device seeking to be employed for the purpose of road safety with the standout features of this device being reduced costs and a multi featured energy efficient approach making this a well designed prototype and a significant competitor in the market.

II. Relevant Work

In 2014, a system was proposed which automatically checks whether the person is wearing the helmet and has non- alcoholic breath while driving. There is a transmitter at the helmet and a receiver at the bike, and switch on the inner surface of helmet to ensure the wearing of helmet. The data to be transferred is coded with RF encoder and transmitted through radio frequency transmitter. The receiver at the bike collects the data and decodes it through RF decoder. MCU controls the function of relay and thus the ignition of engine[3]. Based on the Internet of things (IOT), the proposed device in [4] keeps continuous track of the location and the speed of the vehicle while driving. It also provides the information of helmet being placed on position. All the details can be traced

by the concerned people on Internet/Mobile application. A technique for preventing bike accidents is presented in [5]. The system is designed to lower the risk of death. To ensure that the bike rider is wearing the smart helmet, the author employs an infrared sensor. When an accident occurs, the system recognises it and uses the GSM module to relay an accident location to the nearest hospital. The GPS monitoring device detects the precise position data. A three-axis accelerometer sensor is used to detect an accident. But the failure of medical assistance to reach on time is the leading cause of mortality in most accidents and no one can be notified to the ambulance in distant areas where accidents occur. The work done in [6] suggests a cloud-based accident monitoring system. Motorcycle units, ambulance units, and medical centre units are the three primary units. The system's primary goal is to relay accident sites to the nearest medical facility.Nowadays most of the countries are forcing the motorcyclists to wear helmets and to not exceed the speed limit on their vehicles. Despite this, users continue to violate the rules. Various researchers have focused on employing technological solutions to address this major issue, such as the ignition not starting at all until the helmet is placed on the rider's head. Other sensors can be included to help avoid accidents, these techniques ensure that the rider is wearing the helmet. But there is no mechanism in place to safeguard you before an accident. In [7], a smart helmet collision avoidance system based on a sign board detecting system has been presented. The vehicle is equipped with a microcontroller and a communication system that allows a remote user to monitor it. Shikha Gupta's work in [8] used a variety of sensors in conjunction with a Raspberry Pi to identify alcohol and collisions. The prototype was effective in sending the collision's GPS position as a text message to a remote user via phone. For alcohol detection, an Arduino Uno microcontroller was connected to sensors in a smart helmet. In [9],a system where uses two sets of the control system is proposed where all the communication happens wirelessly via Bluetooth communication from the helmet to the motorcycle control device. A vision-based automatic accident detection system has been developed in [10] where a high definition camera for visual input is used. The raw image is processed in raspberry pi which detects the accident. A cost effective system powered by zigbee is proposed in [11]. It creates a wireless network system with various sensors like a gas sensor and a speed sensor. This system notified to the rider for over speed and also alcohol present in breath.But the ZigBee wireless technology has a high initial cost and lower coverage area. In [12] Arduino NANO and Arduino Mega-2560 are used to control the entire components of the system. GPS and GSM Technology is used for location tracking of the rider sending a text message to the family members during the occurrence of an accident. A smart helmet is proposed in [13], consisting of an accelerometer and a GSM module that detects a fall and sends the information about the fall and its GPS location to an emergency contact over the cellular network.This system tries to deliver the information of an accident to the right people within a few seconds after the accident, so that a quick medical assistance is provided to the rider.

A. *Outcomes of the literature review*

- The proposed design in the previous papers constituted a device that largely involved a simple mechanism to detect accidents
- However we learnt that ensuring minimum occurence of accidents in the first place, is of more value than just to detect them.
- There is a requirement of different sensors such as rain sensors and smoke sensors making our prototype a significant upgrade from the others done previously
- Convenient features such as women safety and bluetooth integration add more value to this work
- An energy conservation approach is to be employed, by using solar panels to power and act as as a secondary storage to our device, thus minimizing battery wastage.
- A cost efficient approach is to be taken in order to increase production and be suitable to the two wheeler wearables market

III. System Design

The device is integrated with a number of interconnected sensors using the Raspberry Pi Microcontroller. The Raspberry Pi 4b is used as the heart of the helmet powering all the necessary sensors to work in real time . Fig 1 depicts the block diagram indicating all the sensors that power the multi featured embedded device .

Fig. 1. Block Diagram of the device

As seen, the device comprises about a total of 20 different hardware components.The combination of these sensors work in real time and thereby enable the systematic working of the key features proposed.

A. Sensors and components used

- Raspberry pi 3b+ as the microprocessor of the device
- Solar panels with a maximum output voltage of 6v
- Raspberry pi camera module 2
- 16*2 LCD Display used as a temporary display for messages and alerts
- MQ2 Gas/Smoke sensor
- MQ3 Alcohol sensor
- An LM393 Comparator chip in the rain sensor with an operating voltage of 5v
- IR/Proximity sensor with an operating voltage of 3.6-5V
- Tilt sensor to detect the accidents with an operating voltage of 3.3-5V
- An active passive buzzer , operating voltage : 4-8V
- A DC motor with an operating voltage of 4.5V - 9V
- Servo motor 5G 90 , Operating voltage of 5V
- A voltage regulator - Input voltage : 0-5 V and Output voltage : 5V
- Lithium Ion Battery (5V)
- Ublox NEO 6M GPS module
- Mini coreless motor 615 , operating voltage : 3.7V

B. Necessary Software

Powered by the Raspberry Pi 3b the device utilizes the following software technologies for its functioning -

- A computer system installed with the **VNC viewer** application acting as the monitor for the raspberry pi
- **Raspbian OS** as its operating system
- **Thonny Python** as the programming language used
- **Twilio** as the platform for interfacing with the position of the device (GPS)

C. Sensors and components enabling key features

1) Solar Panels: As a part of making our approach eco-friendly , we have incorporated our very own solar powered circuit that acts as a secondary source of power supply to the entire setup essentially behaving as a solar powered power bank.

It is crucial to enable the device to be working and powered at all times and also efficiently manage its source of power. This comes as a major advantage during times when the main battery powering the micro-controller becomes overused and also in instances where rain and moisture can affect it. As illustrated in Fig 2, multiple solar panels, a power regulator, and a lithium-ion battery are all part of this circuit. Solar panels are mounted on the top of the helmet and the internal circuitry is attached to the sides. When the panels are exposed to light, they begin to produce energy.The varying intensity of sunlight varies the voltage produced and needs to be stabilized. This is done by using the power regulator which is part of our solar power circuitry. It converts the variable voltage of the solar panels into a constant 5 volt DC. The lithium ion cell is charged with this. In order for full charge of the cell the panel must be exposed to a minimum of two hours of sunlight. The lithium-ion cell is connected to the charging circuit that receives 5 volts (DC) and feeds it to the battery,

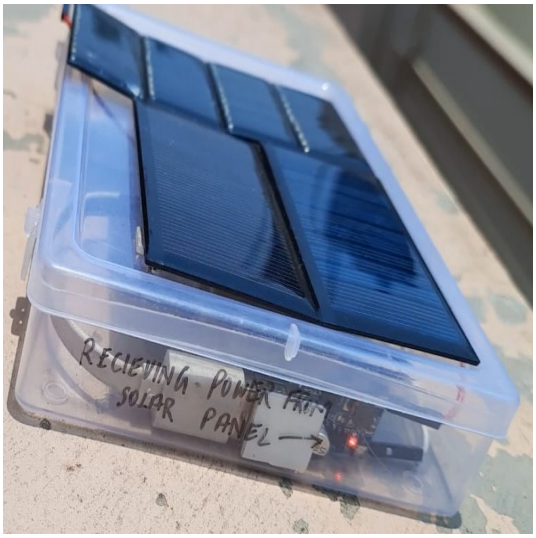

Fig. 2. Solar power circuitry

preventing overcharging and so saving the battery from being compromised. The charging circuit also allows for two-way power exchange, allowing the li-ion to cell be discharged and recharged at the same time. This is done without causing any damage to the battery. The cell may also be charged using standard 5v DC from the main battery. There's a port for this specific purpose in the charging circuit as well and as a result, complete charging is made possible thereby allowing the device to be powered in all times even during rainy weather making this a and sustainable efficient approach to ensure the working of the device.

2) MQ6 and MQ2: One of the main features that lead a significant helping hand in our approach to minimize the risk of accidents is the incorporation of the MQ66 sensor to detect the presence of alcohol. Essentially a metal oxide semiconductor also known as Chemi-resistors,the sensing is executed as a result of the change in resistance of the sensing material when exposed to alcohol. Therefore, on placing it in a simple voltage divider network, alcohol concentrations can be detected. At the point when the objective liquor gas exists, the sensor's conductivity is higher alongside the gas concentration rising, utilizing a straightforward resistive circuit changes over difference in conductivity to the relating yield flag of gas focus. Using the same concept smoke detection in the atmosphere is done by the MQ2 sensor, enabling an alert using the buzzer in both cases of alcohol and smoke. The rider would be alerted to not pursue the route which he or she is travelling because of the presence of excessive smoke and dusty environment.

3) Proximity/IR and Tilt Sensor: Helping to prevent accident using embedded sensors is one of our core agendas. SOS alerts are provided as obstacles or vehicles approach within close vicinity of the riders vehicle using the proximity/IR sensor. With the simple workflow of transmitting and receiving IR waves and calculating the distance during this period (TOF - Time of Flight) we interface the sensor with a buzzer ,

programming it to buzz as an obstacle reaches within a certain threshold distance , close to the vehicle . Since there would exist many blind spots for a rider navigating especially through congested areas and streets this feature lends a significant helping hand in collision avoidance and accident prevention. We have also interfaced a GPS sensor in case of emergency acting as an SOS alert providing the location of the rider to his or her family members and other necessary individuals such as the police. In this prototype, this is done through the software platform twilio. Accident detection is essentially done through the tilt sensors. When the rider faces an accident and falls, the tilt sensor detects the 90 degree rotaion of the helmet and automatically indicates it with a buzzer. The SOS alert is also incorporated when the accident is detected.

4) Women Safety button: The emergency or women safety button is a simple single push button key placed on the side of the helmet. The button is integrated with a buzzer and also the Raspberry Pi OS as well as twilio for the SMS alert in the same fashion as the accident detection. With the threat of unsafe areas and an increase in two wheeler riders being women, their safety is of upmost importance especially during the night in instances where they may be followed by attackers. This feature plays a major role in ensuring that a woman is riding safe and also comes in handy when there is any other emergency.

5) Road sign alerts using machine learning: Key concepts of image processing and machine learning come into the picture in this feature as we utilize TensorFlow in the thonny python software of the raspberry pi to include pretrained models and use them to classify and detect images such as traffic lights , road signs such as school zones, hairpin bends in order to give a preempted alert to the user acing as a warning in case of low visibility and ensuring traffic rules are followed. A camera module, captures these road signs and feeds it to the deep learning algorithm as it is compared with a pre stored database and detected for a particular road sign. This can then be used to provide a voice message over the built in bluetooth headphones of the device. A Convolutional Neural Network is implemented for recognizing the signs and the model is pretrained using a custom dataset. Keras API is incorporated on TensorFlow which acts as the backend and various layers such as max pooling, flatten layer, dense layer are implemented on the sequential model from keras. The key metrics include training loss,validation loss,training accuracy and validation accuracy.

D. Methodology

This section illustrates the systematic working of the device.First, the presence of the helmet is checked through an IR sensor mounted at the top, after which the alcohol sensor detects weather the rider has consumed alcohol and cuts off the engine upon detection, which is temporarily depicted through a DC motor in the prototype which can be replaced with the Engine control unit (ECU) of the vehicle. On the back of the helmet device is another infrared sensor. If other vehicles approach, this identifies them and warns the user. A buzzer sounds when another vehicle draws too close to the user, alerting him and allowing him to take the necessary precautions. The integrated device is powered by solar panels on the top of the helmet. When exposed to enough light, the solar panel itself incorporates a separate charging mechanism that begins charging a lithium- ion battery implanted within the helmet. The principal power source for our circuit is the charge contained in the lithium-ion battery. Alternatively, the lithium-ion battery may be charged with a 5v DC power supply. A fall detection function that employs tilt sensor to deliver necessary signals in the event of an accident is included. with the sensor bent at 45 degrees or more on either of the X axes indicating an accident, but otherwise unharmed. A buzzer rings when an accident is detected, and an SOS message is transmitted to the proper authorities. In the case of an accident, other catastrophic circumstances, or even a vehicle break- down, the user may summon assistance via a specialized switch on the helmet. When this button is pressed, the user's present location is sent to the appropriate authori- ties, along with an emergency call and a request for assistance. The existence of an implanted circuit within the helmet, or unpleasant odor origi- nating from the user's breath, or external heat from the surroundings, may create pain for the rider, with heat being the most significant issue. To address this issue, the helmet has two small exhaust fans on either side, providing airflow and rapid heat dissipation from the gadget. When it rains, a sensor detects dampness from the environment or water particles that have fallen on it and activates a glass viper through servo motors, which cleans the visor of water particles, allowing the rider to see better in the rain. The use of sensors to check for alcohol detection is carried out - the vehicle does not start when the alcohol threshold is exceeded. Another sensor is used to detect the

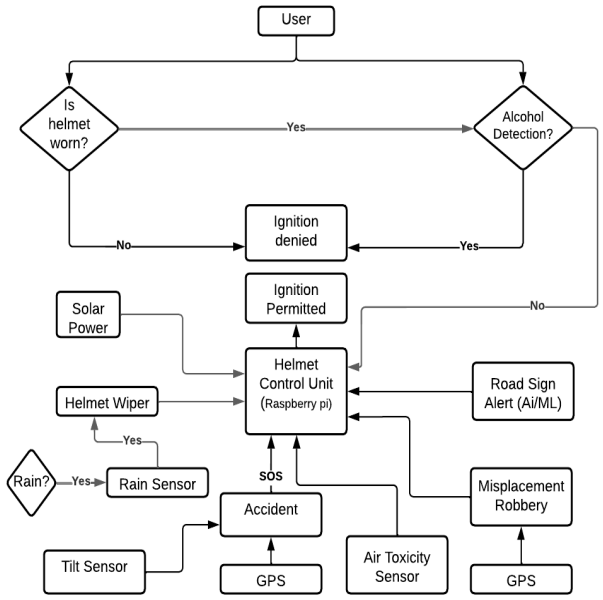

Fig. 3. System Workflow

degree of pollution in the environment. When the threshold is exceeded, the gadget alerts the user, and he may choose another route. There additionaly exists a road sign detection feature in parrallel using machine learning that described in the above section that helps the rider follow traffic signs and warns in case of difficult roadways such as hairpin bends in hilly areas or school zones ahead, thereby significantly contributing for the purpose of road safety. A complete workflow of the above described setup can be seen in Fig 3.

IV. Results

This section illustrates the final prototype developed. The conventional riding helmet comprises of a hard polycarbonate plastic structure which is modified according to the proposed design . The necessary sensors and components are integrated as seen in Fig 4.

Fig. 4. Front view

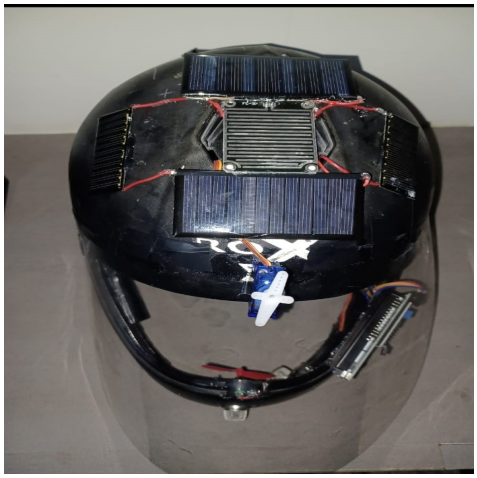

Fig. 5. Top view

Fig 5 shows the top view of the helmet depicting four solar panels employed as they are placed and the rain sensor at the center. The various sensors described in the above section are positioned as shown in Fig 1 of section III

A. *Road sign alert using machine learning*

This feature integrating the camera module as described in section III enables real time detection of incoming traffic signs. The training and test data are divided as 80 to 20 percent . A total of 400 road signs were taken into consideration. We have developed a machine learning model and trained datasets to successfully classify road signs, with datasets incorporated from online databases inclusive of more than 100 per sample (per road sign type). These road signs include a mix of road signs observed in both Germany and India. This feature plays an important role in assisting drivers for oncoming road signs thereby playing a significant part in road safety and reducing the chances of accidents. The trained model after classification yielded 95 percent accuracy in classifying the road signs correctly as a variety of images including blurry, clear and low visibility images were provided for the training dataset. As shown in Fig 6 and Fig 7 , the algorithm using CNN successfully classifies different road signs

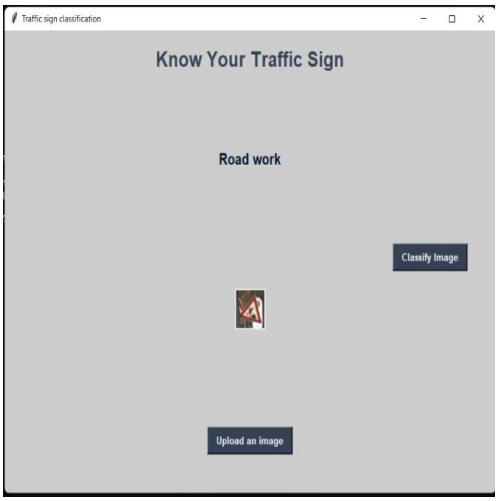

Fig. 6. Road sign type 1

Fig. 7. Road sign type 2

V. Conclusion and future scope

Wearable safety equipment has been able to take an important position in the area of safety devices in a short period and is considered as a business opportunity in the field of automobile industry. With the increase in traffic and exponential rise in the number of accidents there is a demand for safety especially in two-wheeler line-up, in particular India being the home for large number of motorized two wheelers in the world. The ever-growing domain of embedded systems and IoT as well as the increasing need for road safety interests and stimulates us to develop our very own, low cost, secure, embedded wearable device for riders to travel on the Indian roads ensuring safety and comfort. On developing this device we tackle these core issues and satisfy the main objective of our project which is essentially to find an alternative solution to the existing conventional riding helmets and to bring in advanced features for safety and convenience by adapting latest technology with reduced cost to suit Indian markets

In this project we therefore have performed the following:

- Develop a safe wearable device with integrated microcontroller and sensors.
- Provide a safety , reliability and comfort to two wheeler riding
- Lend a significant helping hand in accident prevention.
- Encourage usage of efficient embedded wearable devices.

A. future scope

The proposed device and prototype has an immense scope for enhancement considering the overall structure, efficiency as well as coming up with a business model. The following are some of the ideas and thoughts to increase the potential and further improve the device -

- The design can be combined with wireless communication technology to keep the device connected with the mobile all the time. It will help the rider to receive and disconnect the calls and use the other features like starting the navigation with just a voice command. It will add ease of communication while riding and convenient navigation.
- Integrating the helmet with the two wheeler's engine control system for improved communication.
- A holographic helmet visor can be mounted on a helmet. A transparent screen in the periphery of the motorcyclist's vision, will allow riders to keep their eyes on the road while still maintaining awareness of key riding conditions. Lead metal shielding can be used to make the helmet wearable without endangering the rider from radiation emanating from electronic components. Due to its high density and high atomic number, lead is very effective at shielding the body from radiation sources.
- Making the entire design waterproof to help safeguard sensitive electronics.
- The real-time data can be acquired from sensors within the helmet and transmitted to a server for further analysis. The riders can always be watched over by uploading all the real-time data to the cloud. The parents will find this function helpful in keeping an eye on their children

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