Innovative Helmet Intelligence: Design and Implementation of an IoT-Enabled Smart Helmet with Multi-Sensor Integration for Enhanced Safety.

Varun Poojari[1][0009-0001-1429-5183], Dr. Dhanashri Wategaonkar[6][0000-0001-7049-8594], Shreny Jain[2][0009-0008-7700-7856], Aayush Sandhane[3][0009-0002-4134-0901], Dhruv More[4][0009-0009-8718-4124], Rachit Patekar[5][0009-0007-4888-8503], and Shardul Shekatkar[6][0009-0004-4678-3482]

[1] Dr. Vishwanath Karad MIT World Peace University, Pune 411038, India
varunrpoojari50@gmail.com
[2] Dr. Vishwanath Karad MIT World Peace University, Pune 411038, India
dhanashri.wategaonkar@mitwpu.edu.in
[3] Dr. Vishwanath Karad MIT World Peace University, Pune 411038, India
jainshreny@gmail.com
[4] Dr. Vishwanath Karad MIT World Peace University, Pune 411038, India
sandhaneaayush@gmail.com
[5] Dr. Vishwanath Karad MIT World Peace University, Pune 411038, India
dhruv.r.more14@gmail.com
[6] Dr. Vishwanath Karad MIT World Peace University, Pune 411038, India
rachitpatekar777@gmail.com
[7] Dr. Vishwanath Karad MIT World Peace University, Pune 411038, India
shardul1360@gmail.com

Abstract. With the exponential rise in two-wheeler usage, vehicular accidents, particularly involving motorcycles, have become a pressing concern. Despite the convenience and popularity of motorcycles, accidents have surged, resulting in a significant number of fatalities each year. This paper addresses this issue by introducing the Smart Helmet, an innovative technology designed to enhance motorcycle rider safety. The Smart Helmet incorporates various features, including a helmet detection system to prevent rides without proper head protection, integrated alcohol detection to deter drunk driving, and a dual sensor system to detect crashes and initiate emergency response protocols. The paper also emphasizes minimizing false positives by employing a dual combination of crash detection sensors. By leveraging GSM and GPS technologies, the helmet can promptly alert emergency contacts and hospitals in case of an accident, ensuring timely assistance. Additionally, potential advancements, such as transitioning communication functions to a mobile application, are discussed to improve cost-effectiveness and user experience. Overall, the Smart Helmet represents a promising solution to mitigate motorcycle accidents and foster a safer riding environment.

Keywords: Crash Detection · Minimizing False Positives · Alcohol Detection · Rapid Response · Communication Modules

1 Introduction

Two-wheeler accidents represent a growing concern in today's traffic landscape, with devastating consequences for individuals and communities alike. Defined as any vehicle collision occurring on the road, these accidents are becoming increasingly prevalent, resulting in significant loss of life. According to recent surveys, approximately 7500 individuals lose their lives annually due to motorcycle accidents alone [1]. These tragedies underscore the urgent need for effective interventions to mitigate the risks associated with two-wheeled transportation.

One of the primary contributing factors to the severity of two-wheeler accidents is the reluctance of riders to adhere to safety protocols, particularly regarding helmet usage. Despite ample evidence demonstrating the life-saving benefits of helmets, a large portion of riders continues to disregard this fundamental safety measure. This disregard, coupled with factors such as distraction and violation of traffic laws, exacerbates the likelihood and severity of accidents on the road.

Recognizing the imperative to address this pressing issue, our research endeavors to develop a comprehensive solution that not only promotes helmet usage but also addresses other critical factors contributing to two-wheeler accidents. Our motivation stems from a profound sense of social responsibility to mitigate the loss of life on our roads and create safer environments for all road users.

At the core of our initiative lies the design and implementation of an IoT-enabled smart helmet equipped with a sophisticated array of sensors. By harnessing the power of IoT technology and multi-sensor integration, our innovative solution seeks to revolutionize two-wheeler safety and significantly reduce the incidence of accidents on our roads. Through proactive risk detection, real-time monitoring, and rapid response capabilities, we aim to create a safer and more secure environment for riders and pedestrians alike.

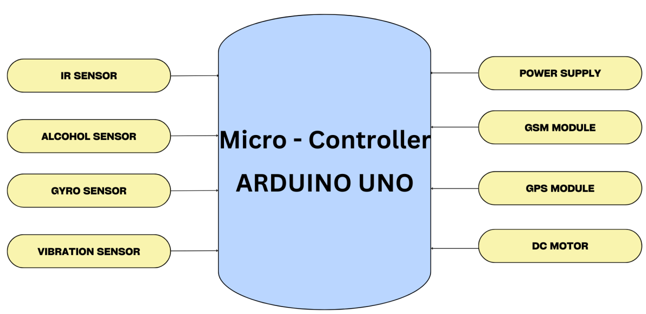


Fig. 1. General Block diagram of Proposed Work

The development of an IoT-enabled smart helmet represents a significant step forward in the ongoing effort to enhance two-wheeler safety. By addressing key challenges such as enhanced crash detection and swift emergency response, our research aims to save lives and prevent countless tragedies on our roads.

2 Literature Review

This section explores a variety of smart helmet designs and the methodologies employed in their development. One such system, proposed by [7], utilizes a Piezo electric buzzer for speed detection, an ALCHO-LOCK technology for alcohol detection, and an accelerometer for accident detection. Additionally, it features a fog sensor to improve visibility in adverse weather conditions and incorporates automated payment withdrawal for fines or penalties.

Another study [8] employs supervised machine learning techniques, particularly Support Vector Machines (SVM), to analyze accelerometer data transmitted via Bluetooth from smart helmets. SVM proves effective in detecting patterns related to accidents and alcohol consumption, contributing to improved safety measures.

In contrast, [9] presents a cost-effective system utilizing ZigBee wireless technology to connect various sensors, including speed and gas sensors, forming a wireless network. This system alerts riders to excessive speed and alcohol levels, albeit with limitations in range and initial cost.

An innovative approach proposed by [10] focuses on the mining industry, utilizing electrochemical sensors to detect dangerous gases and infrared sensors to determine helmet usage. Additionally, Head Injury Criterion (HIC) analysis aids in identifying incidents involving significant head impacts, contributing to improved safety protocols.

Edna Elizabeth's smart helmet system [11] emphasizes accident detection and reporting, leveraging multiple sensors to analyze abnormal variations and trigger emergency services promptly. This system prioritizes real-time communication to ensure timely assistance in critical situations.

Similarly, [12] introduces a system that verifies helmet usage and sobriety before enabling the engine, enhancing safety measures by preventing operation under unsafe conditions. Moreover, it incorporates accident detection and notification features to alert relevant parties promptly.

Further advancements include [13]'s smart helmet system, which provides warnings for unsafe situations and ensures proper helmet fastening to mitigate risks effectively. This system boasts high accuracy rates in functionality and communication tests, demonstrating its reliability in real-world scenarios.

Proposals such as [14] focus on accident reporting and notification, utilizing microcontroller and GSM modules to transmit data to hospitals and emergency contacts via cloud infrastructure. These systems exhibit high performance in identifying accidents and relaying accurate locations, enhancing emergency response capabilities.

Lastly, [15] introduces a sensor-based system that locks the helmet automatically when worn, promoting consistent helmet usage among riders. This system offers real-time monitoring of helmet status and vehicle speed, empowering users with valuable insights into safety practices.

The research aims to contribute to this body of literature by developing a smart helmet system that integrates GPS and MEMS sensors for accident detection and location reporting, alongside alcohol and helmet sensors for enhanced safety measures. The novelty lies in its proactive approach, preventing engine ignition in the absence of proper helmet usage and alcohol detection, thereby prioritizing preventive measures to minimize risks on the road.

3 Proposed Methodology

The proposed methodology for the development and implementation of the Smart Helmet system encompasses several key components aimed at enhancing rider safety and minimizing the risk of accidents. This section outlines the step-by-step approach to designing and integrating the various functionalities of the Smart Helmet as per depicted in Fig.2

1. Ignition Control System:
   The Smart Helmet incorporates an ignition control system that interfaces with the motorcycle's ignition mechanism. If the helmet detects that the rider is not wearing it, the ignition control system automatically disables the bike's ignition, preventing the rider from operating the motorcycle without proper head protection. Similarly, if alcohol consumption is detected through a built-in alcohol sensor, the ignition control system initiates a safety protocol to disable the bike's ignition, thereby preventing drunk driving incidents.

2. Sensor Integration:
   The first step involves integrating essential sensors into the helmet design. This includes: Vibration Sensor: Responsible for detecting sudden impacts or collisions. Gyroscope Sensor: Detects changes in orientation or angular velocity, aiding in crash detection and analysis. These sensors are strategically placed within the helmet to ensure optimal performance and accuracy in detecting potential accidents.

3. Crash Detection Algorithm:
   A sophisticated crash detection algorithm is developed to analyze the data collected from the vibration and Gyroscope sensors in real-time. By examining the readings from both sensors and applying predefined thresholds, the algorithm distinguishes between normal riding conditions and potential accidents. In the event of a crash, where the combined readings of the vibration and Gyroscope sensors exceed the predetermined thresholds, the algorithm triggers an alert mechanism to notify emergency contacts and nearby hospitals.

4. Alert Mechanism:

   Upon detecting a crash, the Smart Helmet activates its alert mechanism, which utilizes a GSM module to send distress messages. These messages include vital information such as the rider's location, obtained through the integrated GPS module, allowing for swift emergency response. Emergency contacts and nearby hospitals are notified of the accident, enabling timely assistance and medical intervention.

5. Buffer Period for False Alarms:

   To mitigate the risk of false alarms triggering the alert mechanism, a buffer period of 30 seconds is implemented. During this buffer period, if the rider deactivates the alert manually, the system resets and resumes normal operation. However, if no action is taken within the specified timeframe, the alert is assumed to be valid, and emergency protocols are activated.

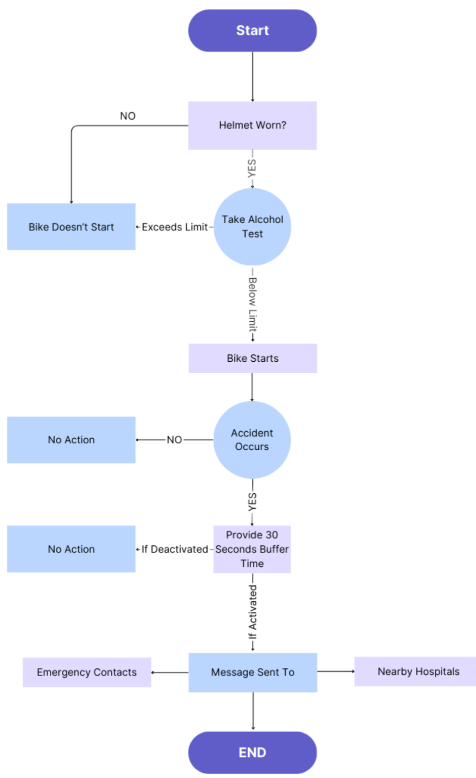


Fig. 2. Proposed System Step-up Process

The development team aims to create a robust Smart Helmet system to significantly improve rider safety, reducing accidents due to negligence or impairment. By addressing false positives, the system enhances accuracy, ensuring reliable performance on the road.

4 Experimental Setup

Fig-2, discuss on the step-up process of our proposed system. Initially an ignition control mechanism is developed to automatically shut down the motorcycle if the rider is not wearing a helmet or has consumed alcohol, ensuring safety compliance. Then the system integrates vibration and Gyroscope sensors into the helmet design to accurately detect impacts and changes in orientation. A sophisticated crash detection algorithm analyzes sensor data in real-time, distinguishing between normal riding conditions and potential accidents. Upon detecting a crash, the system triggers an alert mechanism using a GSM module to send distress messages to emergency contacts and nearby hospitals, including GPS location data for swift assistance. To reduce false alarms, a 30-second buffer period allows the rider to deactivate alerts triggered by non-accident events.

4.1 Basic Requirements

The hardware requirements, sensors and integrated components for the proposed model is presented below:

1. **Arduino Uno:** Arduino excels in interfacing with the external world through its I/O pins rather than its computational power. With 14 digital I/O pins, labeled 0 to 13, it enables control of devices like motors and lights, as well as reading switch states. Each pin can handle up to 40 mA of current, usually adequate for most tasks, although additional interface circuits may be needed for more complex devices. By setting pins to either +5 V or 0 V using C code instructions, Arduino interacts with external circuitry to control devices. Later sections illustrate this process, focusing on interfacing with small motors. Fig.3 portrays the Arduino UNO micro-controller.

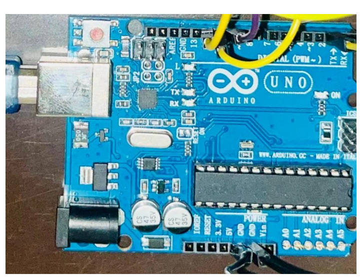


Fig. 3. Arduino UNO

2. Helmet Authentication:

   IR Sensor: An infrared sensor detects specific features of the environment by emitting and detecting infrared light. It can measure an object's temperature and detect motion without emitting its own infrared radiation. Typically, an infrared sensor includes an infrared LED emitter and a photodiode detector. The detector's resistance and output voltages change in response to the amount of infrared light it receives. Operating at 3.6 to 5 V, these sensors have a detection range of 2 to 30 cm. See Fig.4 for an illustration of the IR sensor.

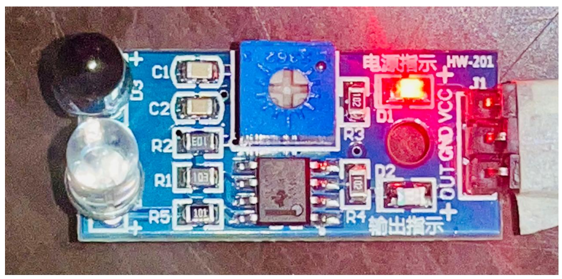


Fig. 4. IR Sensor

3. Alcohol Detection:

   MQ3 Gas Sensor: Integrating the MQ-3 gas sensor fig.5 into a smart helmet enhances rider safety by detecting alcohol vapor in the air. The sensor reacts with alcohol molecules, causing a change in electrical conductivity. This change is converted into an electrical signal, indicating the alcohol concentration. By incorporating this feature, the smart helmet can alert riders in real-time if alcohol levels surpass safe limits, promoting responsible driving and preventing accidents caused by impaired riding.

Fig. 5. MQ3 Gas Sensor

4. Crash Detection:

   SW420 Vibration Sensor: The SW420 vibration sensor is crucial for crash detection, detecting vibrations and shocks by monitoring the movement of a metal ball inside its housing. Configured with a predefined threshold, it triggers upon detecting vibrations exceeding this level. Its analog output interfaces with a micro-controller to analyze signals and identify sudden spikes indicative of a crash. Versatile in automotive, industrial, and consumer applications, the SW420 offers simplicity and reliability, albeit influenced by environmental factors. Calibration and testing ensure consistent performance. Fig.6 depicts the SW420 Vibration Sensor.

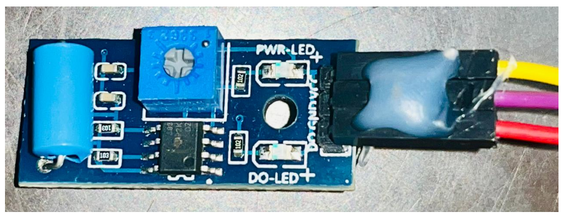


Fig. 6. SW420 Vibration Sensor

   Gyroscope Sensor: This sensor records an object's orientation and angular velocity, surpassing the capabilities of accelerometers. While accelerometers gauge tilt and lateral orientation along with linear motion, gyroscope sensor goes further by also capturing rotational speed and angle changes. Fig.7

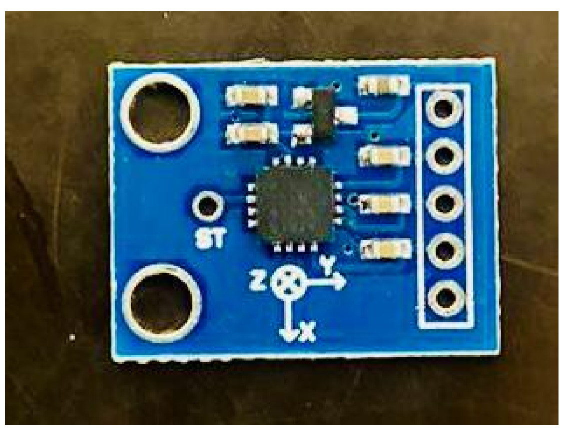


Fig. 7. GY61 Gyroscope Sensor

5. Communication Modules:

   Bluetooth Module: The HC-05 Bluetooth module Fig.8 links an Arduino to a bike's ignition wirelessly, enabling remote control. Commands from a paired device like a smartphone are processed by the Arduino to manage the ignition and control a DC motor's speed and direction. Safety precautions are essential, and users can interact via a smartphone app. Power is drawn from the bike's electrical system, ensuring stable operation. In essence, the HC-05 enhances convenience and safety by wirelessly governing ignition and motor functions.

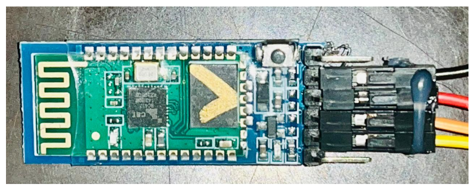


Fig. 8. HC05 Bluetooth module

   GSM Module: GSM stands for Global System for Mobile Communication and refers to a mobile communication modem. Developed by Chime Research facilities in 1970, it has become the most widely used mobile communication technology globally.[1] GSM operates on open and digital cellular networks, utilizing frequency bands such as 850MHz, 900MHz, 1800MHz, and 1900MHz to provide mobile voice and data services. The GSM module HC05, depicted in Figure 9, is a component of this system.

Fig. 9. SIM 800L GSM module

GPS Module: A Global Positioning System (GPS) module receives signals from satellites to pinpoint the device's location accurately. It communicates with multiple satellites simultaneously, calculates its position through triangulation, and outputs this data to connected devices. Factors like satellite visibility and signal obstructions affect accuracy. Integrated into various devices, GPS modules are crucial for navigation and tracking applications.

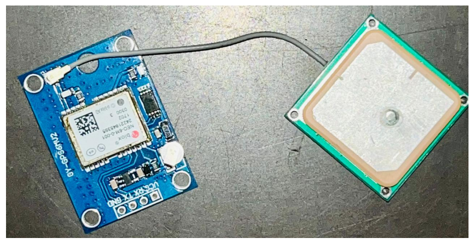


Fig. 10. GPS module

5 Experimental Procedure

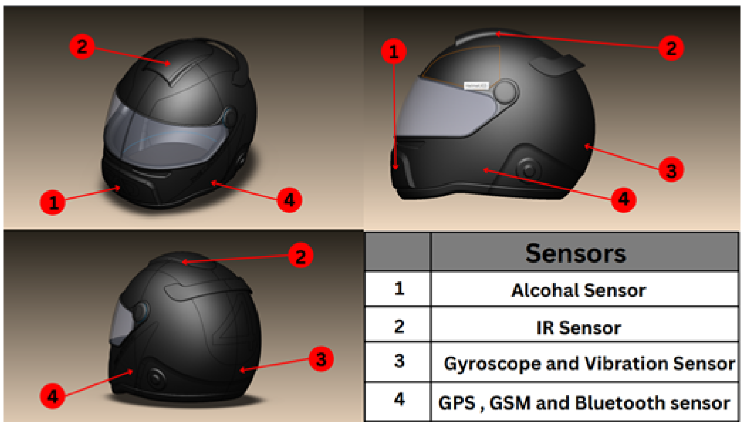
This Smart Helmet incorporates a sophisticated system that detects whether the rider is wearing it or not. If the rider attempts to operate the motorcycle without wearing the helmet, the helmet communicates with the bike's ignition system to automatically shut it off, preventing any further movement until the helmet is properly worn.

Moreover, the Smart Helmet is equipped with advanced alcohol detection technology. If the helmet senses that the rider has consumed alcohol beyond legal limits, it instantly disables the bike's ignition, effectively preventing the rider from operating the motorcycle under the influence.

The Smart Helmet is also equipped with a dual sensor system comprising vibration and gyroscope sensors. In the unfortunate event of a crash, these sensors work in tandem to detect the impact and orientation changes indicative of an accident. Upon such detection, an alert is immediately triggered.

This alert not only notifies the rider but also initiates a rapid response protocol. Utilizing a GSM and GPS module, the Smart Helmet sends distress messages and accident location to predefined emergency contacts and nearby hospitals, ensuring prompt assistance reaches the rider.

In cases where the alert is triggered erroneously, perhaps due to a sudden jolt or intense movement unrelated to an accident, the Smart Helmet offers a grace period of 30 seconds. Within this timeframe, the rider can deactivate the alert, preventing unnecessary panic or confusion. The demonstration of the proposed model is exhibited in the attached Google Drive's video: Working Prototype



	Sensors
1	Alcohal Sensor
2	IR Sensor
3	Gyroscope and Vibration Sensor
4	GPS , GSM and Bluetooth sensor

Fig. 11. Schematic Diagram

Fig. 12. Prototype

6 Discussion

This project prioritizes motorcycle rider safety, addressing three key areas:

1. Helmet Authentication: Verifying helmet usage for head protection.
2. Alcohol Detection: Checking for alcohol consumption to deter drunk driving.
3. Fall Detection: Using dual combination of sensors to accurately detect accidents and minimize false positives.

In case of an accident, GSM technology sends messages with GPS location to enable prompt assistance. A vehicle tracking system prevents theft and monitors rider behavior. Overall, the system aims to rescue riders, promote helmet use, deter drunk driving, and ensure adherence to traffic rules.

7 Conclusion and Future Scope

In conclusion, the development and implementation of the Smart Helmet represent a significant advancement in motorcycle safety technology. By incorporating sophisticated systems for helmet detection, alcohol sensing, and crash detection, this innovative helmet offers a comprehensive approach to rider safety. Its ability to communicate with the bike's ignition system to enforce helmet usage and prevent drunk driving, coupled with its rapid alert system in the event of an accident, demonstrates its potential to mitigate risks and save lives on the road. With its seamless integration of GSM and GPS modules for immediate distress messaging and location sharing, the Smart Helmet ensures timely assistance reaches riders in need. Furthermore, its provision of a grace period for erroneous alerts adds a layer of user-friendliness and reliability to the system. Overall, the Smart Helmet represents a promising solution to enhance motorcycle rider safety and reduce the frequency and severity of accidents on the road.

Looking ahead, there's potential to enhance the Smart Helmet by transitioning communication functions to a mobile application. This move could reduce costs and improve user convenience. By leveraging smartphones, riders could access features like real-time monitoring of helmet usage and alcohol levels. Integrating community engagement and data analytics could further advance motorcycle safety. This shift towards mobile-based technology presents an opportunity to make motorcycle safety more accessible and effective, ultimately leading to safer riding experiences.

Acknowledgements We sincerely thank Dr. Vishwanath Karad MIT World Peace University, Pune, for their invaluable support and guidance during our research. Special appreciation goes to our mentors for their expert guidance and encouragement. We also acknowledge the faculty members for their generous provision of hardware components and unwavering support. Our collaboration with these esteemed individuals and institutions has greatly enriched our research journey.

References

1. M. S. Ram, D. S. Charan, R. Abburi, N. S. K. Raju, G. V. Suraj and S. Samanta, "Design and Implementation of Smart Helmet Based on Iot For Road Accident Detection," 2022 International Conference on Computing, Communication, and Intelligent Systems (ICCCIS), Greater Noida, India, 2022, pp. 467-473, doi: 10.1109/ICCCIS56430.2022.10037610.
2. P. Parameshwari, V. Pujari, and B. Gadgay, "Smart helmet for accident prevention," Int. Res. J. Eng. Technol, vol. 5, pp. 368–370, 2018.
3. S. Sasirekha, S. Swamynathan, Y. Gokul, P. Kirthana et al., "Smart helmet with emergency notification system-a prototype," in 3rd International Conference on Wireless Communication and Sensor Networks (WCSN 2016). Atlantis Press, 2016, pp. 50–56.
4. S. Sasirekha, S. Swamynathan, Y. Gokul, P. Kirthana et al., "Smart helmet with emergency notification system-a prototype," in 3rd International Conference on Wireless Communication and Sensor Networks (WCSN 2016). Atlantis Press, 2016, pp. 50–56.
5. S. Sasirekha, S. Swamynathan, Y. Gokul, P. Kirthana et al., "Smart helmet with emergency notification system-a prototype," in 3rd International Conference on Wireless Communication and Sensor Networks (WCSN 2016). Atlantis Press, 2016, pp. 50–56.
6. S. Sasirekha, S. Swamynathan, Y. Gokul, P. Kirthana et al., "Smart helmet with emergency notification system-a prototype," in 3rd International Conference on Wireless Communication and Sensor Networks (WCSN 2016). Atlantis Press, 2016, pp. 50–56.
7. S. Tapadar, S. Ray, H. N. Saha, A. K. Saha and R. Karlose, "Accident and alcohol detection in bluetooth enabled smart helmets for motorbikes," 2018 IEEE 8th Annual Computing and Communication Workshop and Conference (CCWC), Las Vegas, NV, USA, 2018, pp. 584-590, doi: 10.1109/CCWC.2018.8301639.
8. D. N., A. P. and R. E.R., "Analysis of Smart helmets and Designing an IoT based smart helmet: A cost effective solution for Riders," 2019 1st International Conference on Innovations in Information and Communication Technology (ICIICT), Chennai, India, 2019, pp. 1-4, doi: 10.1109/ICIICT1.2019.8741415.
9. C. J. Behr, A. Kumar and G. P. Hancke, "A smart helmet for air quality and hazardous event detection for the mining industry," 2016 IEEE International Conference on Industrial Technology (ICIT), Taipei, Taiwan, 2016, pp. 2026-2031, doi: 10.1109/ICIT.2016.7475079.
10. S. Chandran, S. Chandrasekar and N. E. Elizabeth, "Konnect: An Internet of Things(IoT) based smart helmet for accident detection and notification," 2016 IEEE Annual India Conference (INDICON), Bangalore, India, 2016, pp. 1-4, doi: 10.1109/INDICON.2016.7839052.
11. D. Selvathi, P. Pavithra and T. Preethi, "Intelligent transportation system for accident prevention and detection," 2017 International Conference on Intelligent Computing and Control Systems (ICICCS), Madurai, India, 2017, pp. 442-446, doi: 10.1109/ICCONS.2017.8250761.

12. A. R. Budiman, D. W. Sudiharto and T. Brotoharsono, "The Prototype of Smart Helmet with Safety Riding Notification for Motorcycle Rider," 2018 3rd International Conference on Information Technology, Information System and Electrical Engineering (ICITISEE), Yogyakarta, Indonesia, 2018, pp. 362-367, doi: 10.1109/ICITISEE.2018.8721027.
13. S. A. Shabbeer and M. Meleet, "Smart Helmet for Accident Detection and Notification," 2017 2nd International Conference on Computational Systems and Information Technology for Sustainable Solution (CSITSS), Bengaluru, India, 2017, pp. 1-5, doi: 10.1109/CSITSS.2017.8447702.
14. Archana D., Boomija G., Manisha J. and Kalaiselvi V.K.G., "Mission on! Innovations in bike systems to provide a safe ride based on IOT," 2017 2nd International Conference on Computing and Communications Technologies (ICCCT), Chennai, India, 2017, pp. 314-317, doi: 10.1109/ICCCT2.2017.7972296.
15. M. Uniyal, H. Rawat, M. Srivastava and V. K. Srivastava, "IOT based Smart Helmet System with Data Log System," 2018 International Conference on Advances in Computing, Communication Control and Networking (ICACCCN), Greater Noida, India, 2018, pp. 28-31, doi: 10.1109/ICACCCN.2018.8748790.
16. J. Ranjani, S. Hariharan, A. Jeyashree and E. Aishwarya, "Saline Infusion Monitoring and Control System Using IoT," 2023 International Conference on Distributed Computing and Electrical Circuits and Electronics (ICDCECE), Ballar, India, 2023, pp. 1-5, doi: 10.1109/ICDCECE57866.2023.10150737.