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A Survey on AI and AR-Based Smart Helmets for Rider Safety

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Abstract - *Motorcyclists are highly vulnerable to accidents due to limited situational awareness, unpredictable road conditions, and lack of advanced safety systems. Traditional helmets provide only physical protection, offering no real-time assistance. This paper proposes an Augmented Reality (AR) Smart Helmet that integrates GPS navigation, weather updates, blind spot alerts, and a rear-view camera directly into the rider's visor. Voice command control enables distraction-free operation, while AI driven crash detection and emergency alert features ensure timely response in critical scenarios. Designed using a user-centered approach, the system enhances rider awareness, reduces risks, and promotes responsible riding practices. The system has been developed using Raspberry Pi Zero, sensor fusion, and AR visualization, and tested in simulated riding environments to evaluate its effectiveness.*

Key Words: Smart Helmet, Artificial Intelligence (AI), Augmented Reality (AR), Internet of Things (IoT), Accident Detection, GPS Navigation, Rider Safety, Emergency Alert System.

1. INTRODUCTION

Road traffic accidents remain one of the most serious global public health concerns, with motorcyclists among the most vulnerable road users. According to the World Health Organization (WHO), over 1.3 million people die in traffic crashes annually, and a significant portion of these fatalities involve two-wheeler riders. Limited physical protection, unpredictable traffic, poor visibility, and adverse weather conditions make motorcyclists highly susceptible to severe injuries. Traditional helmets provide essential impact protection but act as passive safety tools. They do not address modern challenges such as real-time hazard awareness, navigation assistance, or emergency response. Riders often depend on smartphones for navigation or communication, which distracts them and increases accident risk. Moreover, existing systems are often fragmented, offering separate solutions for navigation, communication, and crash detection, which limits their overall effectiveness. Recent advancements in Artificial Intelligence (AI), Internet of Things (IoT), and Augmented Reality (AR) have enabled the development of intelligent safety helmets. These technologies allow helmets to actively monitor surroundings, predict potential hazards, and assist riders in decision-making while maintaining hands-free operation.

The proposed AI-Driven Protection and Augmented Awareness framework bridges the gap between passive protection and active safety by integrating AR-based heads-up display, GPS navigation, blind-spot detection, voice commands, and AI-powered crash prediction. In the event of an accident, the system can automatically send an SOS alert with GPS coordinates to emergency contacts, ensuring a prompt response. By combining proactive hazard alerts with automated emergency actions, the Smart Helmet functions as an intelligent riding assistant that enhances safety, reduces distraction, and encourages responsible riding. This research contributes to the advancement of intelligent transportation systems (ITS) by presenting a scalable, technology-integrated solution to improve motorcyclist safety.

2. NEED OF PROPOSED SYSTEM

Motorcyclists remain highly vulnerable due to limited protection and situational awareness. Conventional helmets offer only passive safety and fail to address real-time challenges like poor visibility and sudden lane changes. Smartphone use for navigation further increases distraction and accident risk. Therefore, integrating Artificial Intelligence (AI), Internet of Things (IoT), and Augmented Reality (AR) can create an intelligent helmet that actively enhances rider safety.

The proposed Al-driven AR Smart Helmet aims to:

- Enhance situational awareness by displaying real-time data such as navigation routes, weather updates, and obstacle proximity on an AR visor.
- Detect potential hazards and accidents proactively using Al and sensor fusion.
- Enable hands-free operation through voice commands to minimize distractions.
- Ensure rapid emergency response through automated SOS alerts with GPS coordinates.

3. RELATED WORK

Research on smart helmets has grown rapidly in recent years:

- Navigation-focused helmets overlay GPS routes but often lack safety modules.
- IoT-based helmets detect crashes and send alerts but are reactive rather than preventive.

- Blind-spot monitoring systems improve visibility but do not integrate AR feedback.
- AR-based prototypes exist but are limited to partial functionality without full AI integration.

4. ADVANTAGE OF PROPOSED SYSTEM

The proposed Al-driven AR Smart Helmet offers several advantages over existing solutions in terms of safety, usability, and technological integration. Unlike conventional helmets that focus solely on protection after an accident, this system emphasizes proactive accident prevention, real-time awareness, and seamless communication. The key advantages include:

- **Enhanced Situational Awareness:** Real-time AR overlays provide riders with navigation, obstacle alerts, and weather updates without diverting their attention from the road.
- **AI-Based Hazard Detection:** Sensor fusion using accelerometer and gyroscope data enables early identification of abnormal riding patterns or collisions.
- **Hands-Free Control:** Voice-command integration allows riders to interact with the system safely without manual intervention.
- **Integrated Safety Mechanisms:** The helmet combines preventive and reactive safety features such as blind-spot monitoring, crash detection, and automatic SOS alerts.
- **Energy Efficiency:** The system is designed with optimized power consumption, ensuring extended operation without frequent recharging.
- **User-Centric Design:** With a simple and intuitive interface, the helmet minimizes distractions and enhances user comfort.
- **Cost-Effectiveness:** The prototype offers mid-range affordability while incorporating multiple high-end features found in premium commercial helmets.

5. COMPARATIVE STUDY

To evaluate the performance and practicality of the proposed system, a comparative study was conducted with existing smart helmets available in the market. Table?? Summarizes the key differences based on critical performance criteria such as navigation, safety, communication, usability, battery life, and cost.

As shown in Table-1, the proposed system outperforms existing helmets by providing a balanced combination of safety, intelligence, and affordability. Unlike commercial models that prioritize entertainment or partial navigation assistance, the proposed design integrates AI-driven accident detection, AR-based visualization, and IoT-enabled emergency response, making it a more comprehensive and reliable safety solution for riders.

Table -1: Comparative Study of Proposed System with Existing Smart Helmets

Feature/ Criteria	Proposed System: Smart Helmet	Existing System 1: Livall Smart Helmet [5,6]	Existing System 2: Sena Smart Helmet [9]	Existing System 3: Skully AR-1 [10]
Navigation Guidance	Real-time audio/visual cues	Limited	None	HUD with navigation
Safety Features	Collision, fall detection	SOS alert, integrated lights	None	Rearview camera
Communication	Voice commands, mobile app	Music and calls via Bluetooth	Music and calls via Bluetooth	Music and calls via Bluetooth
Ease of Use	Voice commands, simple UI	Integrated lights and signals	Voice commands	HUD, complex UI
Battery Life	Long-lasting, energy-efficient	Decent	Decent	High power consumption
Cost	Mid-range	Affordable	Affordable	Expensive

6. PROPOSED SYSTEM

The proposed AR Smart Helmet system is designed as an intelligent, IoT-enabled safety solution that integrates hardware and software components into a compact, wearable platform. The Proposed system architecture, illustrated in Fig. 1, is based on a layered design to ensure modularity, real-time processing, and efficient data communication.

At its core, the Raspberry Pi Zero acts as the central processing unit, interfacing with various input and output modules through serial and wireless connections. The helmet continuously collects and processes real-time data to provide navigation guidance, safety alerts, and emergency notifications.

6.1 Input Modules

The input subsystem consists of multiple sensors and components responsible for environmental and motion data acquisition. These include:

- **GPS Module:** Provides continuous location tracking for route navigation and emergency geolocation.
- **MPU6050 Accelerometer and Gyroscope:** Detects motion, tilt, and sudden impacts to recognize potential accidents or risky maneuvers.

- **Pi Camera:** Mounted at the rear to monitor blind spots and identify surrounding vehicle movement.
- **Microphone:** Enables hands-free control through voice commands, reducing manual interaction while riding.

6.2 Output Modules

The output subsystem delivers real-time information to the rider through visual and auditory channels.

- **AR Visor Display:** Projects navigation routes, hazard warnings, and real-time notifications directly onto the rider's field of view, ensuring minimal distraction.
- **Speakers and Audio Alerts:** Provide voice-assisted navigation, traffic warnings, and confirmation of system commands.
- **GSM/Bluetooth Module:** Facilitates communication between the helmet and external devices, enabling automated SOS alerts or integration with smartphones.

The control logic within the Raspberry Pi Zero ensures synchronization between the input and output subsystems. It processes sensor data through AI algorithms and generates contextual alerts within milliseconds, ensuring proactive rider safety.

7. METHEDOLOGY

The proposed system follows a systematic, five-stage methodology from hardware integration to emergency response. Each stage focuses on achieving real-time awareness and safety automation for the rider.

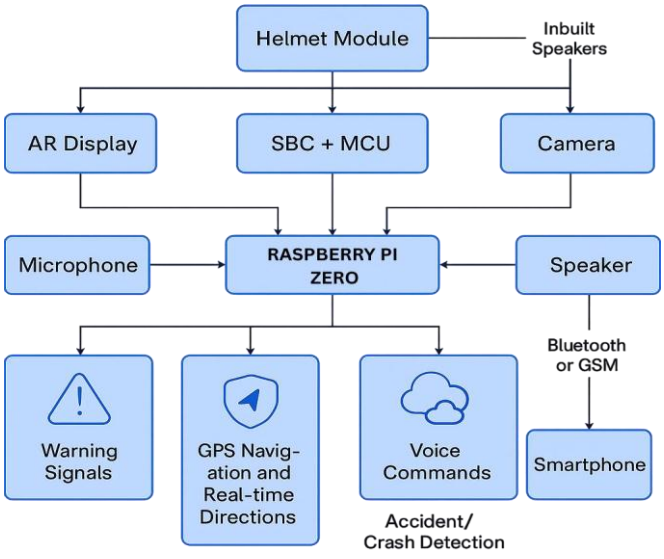

Fig -1: Proposed Smart Helmet System Architecture

7.1 Helmet Module Integration

The helmet acts as the primary housing unit for all hardware modules. The AR visor, camera, and communication modules are ergonomically positioned to minimize rider discomfort. The Raspberry Pi Zero coordinates all peripheral modules through GPIO and serial connections, ensuring efficient power and data management.

7.2 Data Acquisition

Sensor data is continuously collected from the GPS, accelerometer, gyroscope, and camera in real time. The accelerometer and gyroscope track motion vectors and tilt angles, allowing the detection of sharp turns, falls, or collisions. Simultaneously, the rear camera provides a live video feed that is processed to detect blind-spot vehicles or environmental obstacles.

7.3 AI Processing

Collected sensor data is analyzed using a trained AI model based on supervised learning. Implemented with TensorFlow Lite, the model classifies rider behavior as normal, hazardous, or crash. Sensor fusion of accelerometer and gyroscope data enhances accuracy and reduces false positives. Real-time inference on the Raspberry Pi allows adaptive detection under varying riding conditions.

7.4 Output and Feedback

Once processing is complete, the output subsystem delivers real-time feedback through visual and audio interfaces. The AR visor overlays navigation cues, speed limits, and obstacle warnings, allowing riders to keep their eyes on the road. Concurrently, audio prompts supplement visual cues for improved accessibility and safety.

7.5 Emergency Response

When an accident or severe fall is detected, the system automatically triggers the emergency response module. The GSM unit sends an SOS message containing the GPS coordinates, timestamp, and rider identification details to predefined emergency contacts. This automated response minimizes reaction time and ensures rapid medical assistance.

9. CONCLUSION

This survey reviewed the evolution and current landscape of AI and AR-based smart helmet systems, highlighting major innovations, limitations, and research gaps. Building upon this foundation, a unified AI-driven AR Smart Helmet framework was proposed to enhance both preventive and reactive safety features. By combining multi-sensor fusion, real-time visualization, and autonomous communication, future iterations of such helmets can substantially reduce rider risk and redefine safety standards for modern transportation.

REFERENCES

[1] A. Bhamare, S. Jagtap, O. Bhore, P. Pedhekar, and V. Atharale, "Smart Helmet with User Navigation Guidance Support," 2024 8th International Conference on Computing, Communication, Control and Automation (ICCUBEA),2024. https://doi.org/10.1109/ICCUBEA61740.2024.10774715.

[2] A. George, A. Thomas, A. Abraham, J. Jose, and J. Joseph, "SAFE RIDE: An Integrated Bike Safety System with Crash Detection," Proceedings of the 7th International Conference on Intelligent Sustainable Systems (ICISS-2025),2025. https://doi.org/10.1109/ICISS63372.2025.11076269.

[3] M. H. Khan, F. Tasnim, M. R. Uddin, S. Banik, and M. Hasan, "An Adaptive Fast-Response Sensor Integrated Smart Helmet for Blind-Spot Protection and Guidance to Avoid Unavoidable Occurrences," Proceedings of the 7th International Conference on Inventive Material Science and Applications (ICIMA-2025), 2025. https://doi.org/10.1109/ICIMA64861.2025.11073922.

[4] S. R. Swamy, H. Deepanjali, A. Aryan, A. Kishore, A. Karan, and N. Prasad, "Design and development of AI - IoT based smart helmet to ensure safe driving," 2025 3rd IEEE International Conference on Knowledge Engineering and Communication System (ICKECS-2025),2025. https://doi.org/10.1109/ICKECS65700.2025.11036017.

[5] S. S. Rachel, P. H., and Y. R., "Accident detection based on IoT using smart helmet," 2025 International Conference on Computing and Communication Technologies (ICCCT),2025. https://doi.org/10.1109/ICCCT63501.2025.11019230

[6] G. Gerentes, A. Leonidis, N. M. Stivaktakis, M. Korozi, and C. Stephanidis, "Enhancing Motorcycle Safety Through Augmented Reality: Design and Development of a Smart Helmet Prototype," Human Factors in Design, Engineering, and Computing, vol. 159, pp. 1089–1099, 2024. https://doi.org/10.54941/ahfe1005675.

[7] K. Saranya, C. Santhosh, D. Ramkumar, M. A. Chockalingam, and S. Naveen, "Collision Prevention Technology in IoT Integrated Smart Bike Helmet," 2025 International Conference on Data Science, Agents, and Artificial Intelligence (ICDSAAI), 2025. https://doi.org/10.1109/ICDSAAI65575.2025.11011714.

[8] P. Gahane, S. Sahare, Y. Lambat, A. R. Raut, and P. Rathi, "Smart Helmet: A New Generation Helmet," 2022 International Conference on Recent Trends in Microelectronics, Automation, Computing and Communications Systems (ICMACC), 2022. https://doi.org/10.1109/ICMACC54824.2022.10093342.

[9] V. Maheshwari, T. Khandelwal, D. Gulati, and D. Agarwal, "Smart Helmet: A Comprehensive Solution for Rider Safety," 2025 3rd International Conference on Disruptive Technologies (ICDT), 2025. https://doi.org/10.1109/ICDT63985.2025.10986370.

[10] S. Akter, M. A. Yousuf, K. M. R. Alam, M. Sahidullah, M. M. Islam, and J. Uddin, "A Cost-Effective Smart Helmet for Human Safety and Road Accident Detection Using IoT," 2024 International Conference on Recent Progresses in Science, Engineering and Technology (ICRPSET), 2024. https://doi.org/10.1109/ICRPSET64863.2024.10955923.

[11] Z. Xiong, J. Zhang, Y. Cai, and J. Dong, "Design of A Smart Safety Helmet Incorporating Observation, Communication and Localization Functions," 2024 39th Youth Academic Annual Conference of Chinese Association of Automation (YAC), 2024. https://doi.org/10.1109/YAC63405.2024.10598653.

[12] M. Tamilarasi, S. Chitra, N. Barathkumar, S. Bhuvanesh, and C. Dhineshwaran, "Smart Helmet with Transparent Display," 2024 4th International Conference on Intelligent Technologies (CONIT), 2024. https://doi.org/10.1109/CONIT61985.2024.10627271.

[13] S. B. Abitha, R. Santhoshi, B. B. Sangameswaran, K. Shivashanker, S. Balakrishnan, and V. Tharun, "Armor Guard: Revolutionizing Motorcycle Safety with Smart Helmet," 2024 International Conference on Computing, Sciences and Communications (ICCSC), 2024. https://doi.org/10.1109/ICCSC62048.2024.10830429.