IoT-Based Integrated Heads-Up Display for Motorcycle Helmet

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***Abstract*—The prevalence of visual impairment among the global population is a growing concern, with rates continuing to rise at an alarming pace. According to statistics from the World Health Organization (WHO), an estimated 2.2 billion people globally live with some form of visual impairment. Several methods exist to aid the blind in everyday navigation, such as walking sticks and guide dogs. However, these aids do not come without their drawbacks. For instance, using traditional guide dogs may not be suitable for some individuals due to allergies, cultural beliefs, or being unable to take care of a living animal due to the level of responsibility required. Innovations such as smart walking sticks and robotic guide dogs are continually being developed to overcome these gaps and cater to the unique requirements of the visually impaired. Hence, this proposed system is equipped with a joystick-controlled robotic guide that mimics the responsibilities of a traditional guide dog. The proposed system features an obstacle avoidance feature that will detect obstacles in its environment to avoid collisions. It will also provide audio feedback through a Bluetooth-connected mobile application when an obstacle has been detected. The proposed system is a product innovation which can be targeted to benefit visually impaired users by providing them with more independence as well as convenience in terms of mobility. Upon performing acceptance testing with the target audience, the system has been found to achieve its target in aiding the guidance of blind individuals.**

Keywords*—*Heads-up display; motorcycle helmet; Internet of Things (IoT); android application; Raspberry Pi; product innovation

I. Introduction

In 2015, the United Nations (UN) created the 17 interrelated global goals, also referred to as the Nation Goals or Sustainable Development Goals (SDGs). By 2030, a more equitable and sustainable future is to have been established, and many of the world's social, economic, and environmental problems are to have been resolved. SDG 9 is about infrastructure, industry, and innovation; HUD is in line with this objective. HUD technology integrated into motorcycle helmets can provide real-time navigation, weather updates, and speed information directly in the rider's line of sight. This not only enhances the riding experience but also promotes road safety by minimizing the need for riders to look away from the road [1-2].

Helmets are protective headwear that shields the head and brain from injury during a range of activities, especially ones that include the risk of impact or falls. As previously indicated [3 - 5], the present generation of helmets is lacking significantly, especially considering the increasing prevalence of the Internet of Things (IoT) [6-9] and its use in the automobile sector, including automated braking, head-up displays, and other features. Helmets are used for many different purposes and can be found in many different forms. Motorcycle riders make up the majority of road users, however, because there is a lack of innovation and products in the ASEAN market, the helmet is seen as a less important part of the IoT. IoT are deployed in several applications for the convenience of users [10-12].

The idea for heads-up display systems was initially created for use in automobiles, including commercial aircraft, cars, and military vehicles. To make sure they are free of any obstructions, any user can flip between the two cameras that surround the car and the aeroplane. Operating the gadget is as simple. The navigation system is one of its main benefits; it keeps the pilot or driver focused on manoeuvring the vehicle rather than getting distracted [3,13]. The LCI-HUD Helmet System makes use of the same capability. The main CPU board is the Raspberry Pi, which is also equipped with Bluetooth.

A camera mounted behind the rider's helmet does double duty as a rearview mirror and, more importantly, closes the blind spot for motorcyclists. On the other hand, the helmet's built-in headset allows the rider to talk hands-free while answering calls or listening to music. A button on their visor controls the display.

A map navigation display appears on the device once the user uses the mobile application to set the destination on the helmet. Using the music application, the rider can also play music via a playlist display on the visor. Rather than pulling over to the side of the road to answer a call, the rider can use [8] to answer hands-free. Information about the caller will be shown on the visor using the HUD system. This reduces the possibility that the rider will drive while distracted.

Fig. 1 illustrates the proposed work, which is an improved low-cost integrated head-up display (LCI-HUD). A multitude of information can be projected onto the HUD by integrating the LCI-HUD with currently running third-party applications. One crucial element is the concept of an inexpensive, multipurpose LCI-HUD. Users can retain their user data using LCI-HUD after installing and registering mobile apps. APIs are used to connect the music and additional third-party extensions. LCI-HUD integrates as a result. LCI-HUD interacts with third-party applications to provide users with immediate access to a range of services, including social media notifications, navigation, and weather updates, on the HUD. This seamless connectivity offers convenience while driving, enhancing the user experience all around. The use of APIs ensures that the LCI-HUD stays up to date with the latest features and advancements in third-party apps.

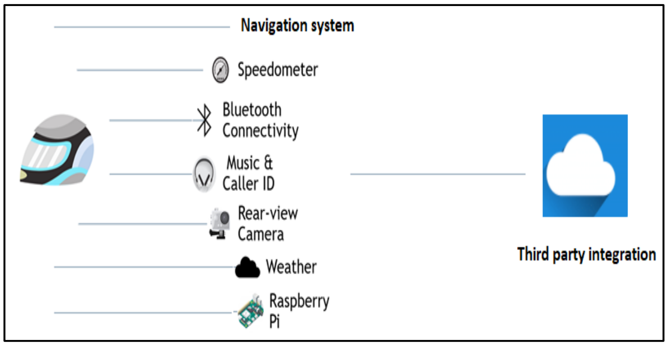

Fig. 1. Integrated heads-up display.

To check blind spots or view dashboard information like the speedometer, riders donning the existing (non-HUD) helmet are compelled to glance away from the road. Additionally, call receiving and navigation are done via external devices like cell phones. Roadside incidents are dangerous because they require quick attention and are easy to miss; using these devices could cause a shift in focus. Driving will become safer and less frequent if drivers maintain their attention on the road. To monitor blind areas or view dashboard information like the speedometer, riders using the existing (non-HUD) helmet are forced to turn their heads and look away from the road. In addition, calls and navigation are handled by external devices, like smartphones. Because road incidents are time-sensitive and easy to overlook, these devices will cause a shift in attention and pose a risk. The number of incidents will go down if drivers keep their eyes on the road for a safer driving experience.

The transparent display of HUD technology allows riders to view data without having to shift their typical range of vision, which is why it is recommended. Driving safety could be increased with the use of HUDs. Head-up display (HUD) navigation on a motorcycle is safer than smartphone navigation, according to a previous study. Additionally, by connecting the LCI-HUD with pre-existing third-party applications, it may show a variety of data on the HUD. There are several features available on the market for a fair price for the proposed LCI-HUD. The LCI-HUD can save user data after users install and register it. The integration of LCI-HUD follows. The small, lightweight additional hardware on the helmet won't restrict rider mobility.

To reduce distraction, motorcyclists can designate their preferred destination on their phone through the navigation module, and it will appear on the visors of their helmets [6]. To lessen the additional weight required to construct a bespoke board with the navigation module and to lower the cost of the hardware, the navigation module will retrieve navigational data from the smartphone. A weather module is added to assist the riders with changes in the weather. When motorcyclists are aware of the weather ahead of time, they may carefully plan their route.

The caller ID module enables the rider to receive a phone call with a pop-out on the rider's visor. Using a button mounted on the handlebar of the bike, riders can answer or reject phone calls. Passengers can use the Music Module to adjust the music on their phones. To forward or rewind the music, a button is attached. Information is continuously shown on the visor via the Rear-View Camera Module, which is mounted to the back of the helmet and functions like a rear-view camera. By doing this, bikers will be able to avoid their blind spot and feel more confident when changing lanes without looking back.

As seen in Fig. 2, the user must first register for the mobile application. Using Firebase, the user will be able to access and exit the database remotely, and this data will be stored online. The rider and the Raspberry Pi must be connected via Bluetooth. The mobile application primarily controls two functions: music and navigation. The LED button on the Raspberry Pi allows the rider to select the display on the visor. The modular HUD's hardware will feature a camera affixed to the back of the helmet to function as the rear view and more sensors that the user can add in the future. The weather conditions displayed on the visor and data access are also guaranteed by the Raspberry Pi.

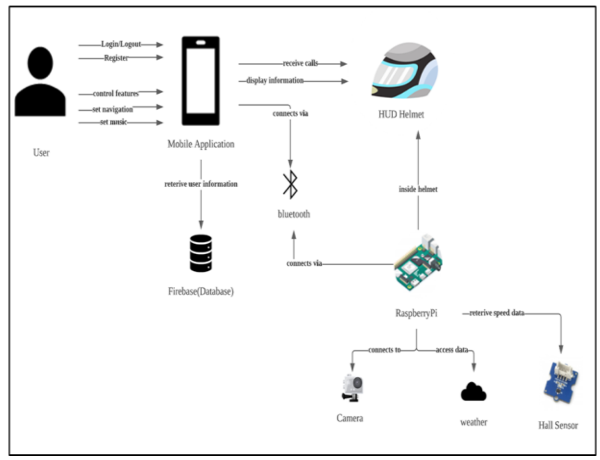

Fig. 2. Rich picture diagram.

II. Literature Review

There are two methods utilised to collect the necessary data: surveys and interviews. The target user base for data gathering is riders, to compare the proposed HUD helmet system with the existing helmet. The plan aims to boost safety while highlighting life experience in contrast to the existing helmet. The surveys will provide quantitative data on user preferences and feedback, while the interviews will offer qualitative insights into user experiences and suggestions for improvement. By targeting riders specifically, the research focused on the primary users of the HUD helmet system to ensure that safety and user experience are prioritized in the development process.

A. Requirements Phase

The interviews reveal information on the riders' perspectives and experiences with the existing helmet, as well as any prospective upgrades. The riders' preferences and perceptions of safety elements were quantified using questionnaires. Better user experience and more safety precautions were ensured by customizing the proposed HUD helmet system to the needs and preferences of the target users through their involvement in the data collection process. Motorbike riders were provided with a web-based questionnaire comprising multiple choice questions as part of the quantitative approach. Fig. 3 illustrates riding conditions that can cause distraction. Fig. 3 also presents the data collected on "distraction resulting from current riding experience.

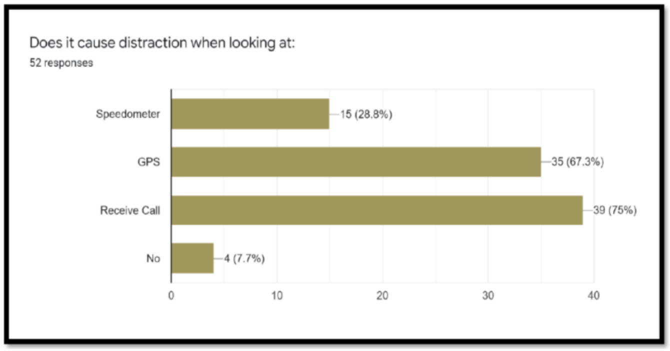

Fig. 3. Distraction due to current riding experience.

The intended LCI-HUD system as well as traditional helmets were the subjects of interviews conducted using qualitative methods. The purpose of the information gathering was to raise awareness about the HUD system in helmets and study any extra features that might be needed, in addition to the basic sensors and features. The HUD Helmet System can help when riding in accordance with the feedback that was received. Since it has features that make riding more convenient, the HUD Helmet System is preferred for use. It also helps to integrate everything together. The interviewee also offers suggestions for future developments that might be made to the HUD Helmet, including voice command, predictive braking distance, lane departure warning, and lane maintain assist. Beyond the advantages of using the existing helmet, the HUD Helmet System also offers the user benefits. To lessen the necessity of constantly checking his phone while riding, another interviewee indicated that he currently wears Bluetooth headphones. In line with other interviewees' responses, the information the respondent desired to have in the helmet—namely, navigation and display speed was also advantageous. Since it needs to determine the speed limit on the road where the rider is, the additional features, like the over-speeding warning message, could be a future enhancement. As conclusion, the interviewee believes that having a HUD helmet system is a good concept since it will assist motorcyclists stay focused because information is displayed on the visor.

B. Design Phase

Fig. 4 displays the activity diagram flow that outlines the riders' involvement, beginning with opening the LCI-HUD app and identifying whether they are first-time users. Once the registration procedure is complete, riders can log in. Riding the LCI-HUD system requires a Bluetooth connection after logging in. Following connection identification, riders can exchange visor information by pressing the LED button. Navigating while maintaining eye contact with traffic is made possible for riders by HUD helmet technology. By putting notifications, speed, and navigational data in real-time right in the rider's line of sight, this technology improves safety. Rider customization and distraction-free connectivity are made possible by the LED button, which allows riders to quickly switch between visor information.

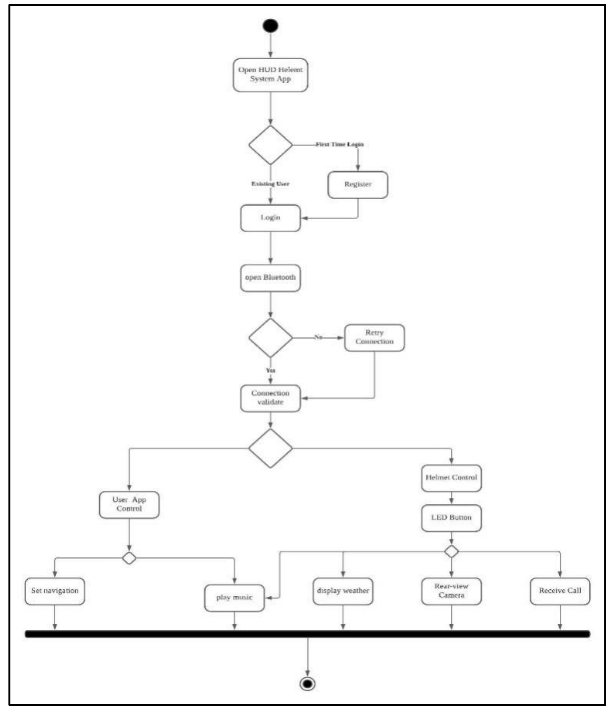

Fig. 4. Activity diagram.

As shown in Fig. 5, the characteristics that are used to specify objects form the basis of the class diagram. The UserID, a primary key that is automatically assigned to the rider at registration, is one of the features in the user database. The Bluetooth host is identified as the user's mobile phone. The further prerequisites are a password, phone number, and email address. The rider and the LCI-HUD system table will be connected via the database table. There are many relations; they are switched between one-to-many in the database and one-to-one in the LCI-HUD system by the database table. This suggests that a single user might be a part of many LCI-HUD systems and accounts. The table contains the board Bluetooth receive address and unique main key for HUD-based helmet system identification. Every user in the database table has a unique identity according to the primary key. There is an assurance that no two users are utilizing the same ID. To enable secure communication and data transfer between the user's helmet system and the LCI-HUD system, the Bluetooth receive address is utilized.

Fig. 6 shows the proposed LCI-HUD system's conceptual configuration. The schematic arrangement of the proposed LCI-HUD system is shown in Fig. 6, which also gives an idea of how the various parts are connected. This diagram facilitates the process of implementing and debugging the system by helping to comprehend its general structure and functionality. The brown cable is a camera module that is attached directly to the CSI port. The black GrovePi+ cable allows the sensor module to be operated directly from a socket. The orange wire, which is connected to the hall sensor and speedometer, respectively, is what powers the LED button. The last cable, which is blue, connects to the headset via the 3.5mm audio connector.

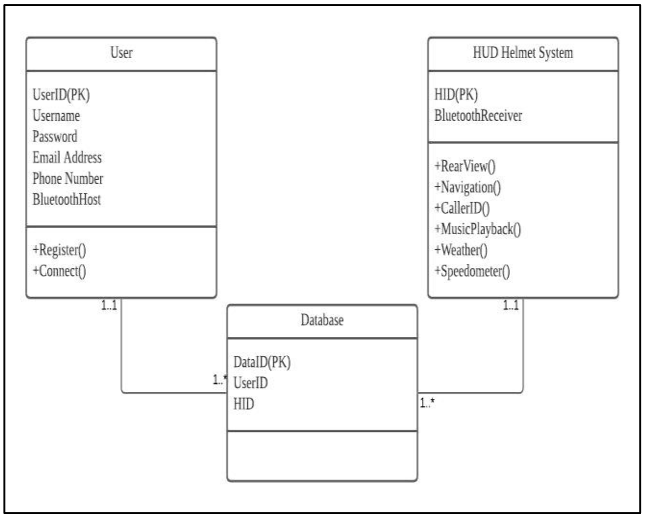

Fig. 5. Class diagram.

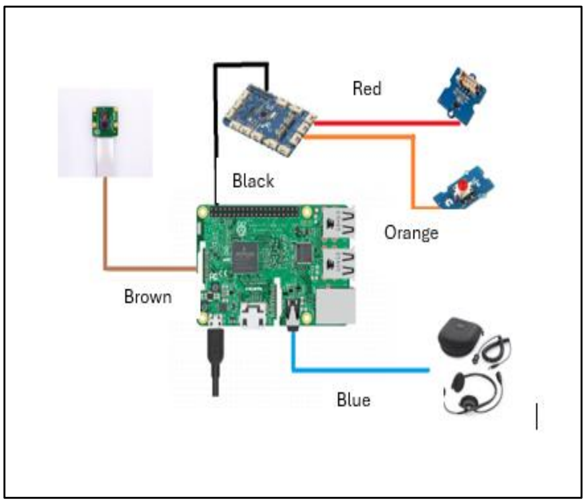

Fig. 6. Schematic layout of the proposed HUD helmet system.

C. Implementation Set-up

A Raspberry Pi, an Android app, and a database were employed as development platforms. Python and a JavaScript file for the LCI-HUD system were used to execute GeanyIED. Using the Pixel 2 as a reliable test bench, Android Studio emulates Android 8.0. Using a mobile app, Google Firebase stores authentication and databases. The users/rider need to register before using the application.

Module design is done in the Geany IDE. The framework of the HUD helmet system is written in Python using the Geany IDE. All the essential tools required for debugging and running code are included. Developers may use Android Studio to create phone apps that function across a variety of devices and run on the Android operating system. Using Firebase DB, the primary software feature, apps linked to the Raspberry Pi (HUD Helmet) can update the database in real time, enabling the Internet of Things. The system begins to communicate with and store information about the user as soon as they register for the first time on the mobile application. Following that, users run the system via Bluetooth. For security purposes, only the user has access to a unique authentication token.

The main objective of the system's implementation and appropriate functioning are its functional prerequisites. The non-functional need focused on the five main elements, along with other demands that were related to the behavior of the system's interactions, or the time required to finish a specific task. Usability, security, accessibility, user engagement, and responsiveness are the non-functional requirements for the suggested HUD Helmet System. The responsiveness criterion makes ensuring that user inputs are processed fast and effectively, and that real-time feedback is provided. The criterion for accessibility makes sure that users with impairments or disabilities can navigate the system with ease. Providing a smooth and simple user experience that makes it easy for users to explore and interact with the system's capabilities is the main goal of the user interaction requirement. The system is safeguarded against unauthorized access and data breaches thanks to the security requirement. Making the system simple to use and intuitive to understand is the main goal of the usability requirement.

III. Results and Discussion

Fig. 7 illustrates the three "modules" that the user of the LCI-HUD App can access on the first page after setup which includes the clock, weather, and rear-view camera. Since it is always necessary for the user to see the blind spot, the rear-view camera module remains stationary. By doing this, the user can continuously monitor the stream from the rear-view camera without ever leaving the first page. The clock and weather modules can also be customized by the user to show information that they want, like the location of weather updates or the format of the time.

The user can choose, edit, or remove data for numerous HUD helmet devices on the left page, as shown in Fig. 8. Users can flip between pages and change the brightness on the right page of the HUD helmet. The right page of the HUD helmet allows for simple page switching, offering a fluid and adaptable experience. Additionally, the brightness control feature guarantees the best possible visibility under different lighting circumstances.

When the user clicks on the red button as shown in Fig. 7. That will be simulated installed in the handler bar of the motorbike this will scroll to the next page as shown in Fig. 9 which at the moment showing the Google map route and music. User are able to expand on this by customizing it for which other widgets that they wish to view at a glance from the LCI-HUD App.

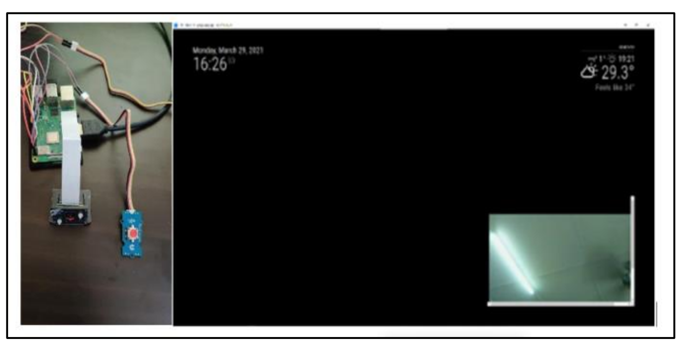

Fig. 7. LCI-HUD System.

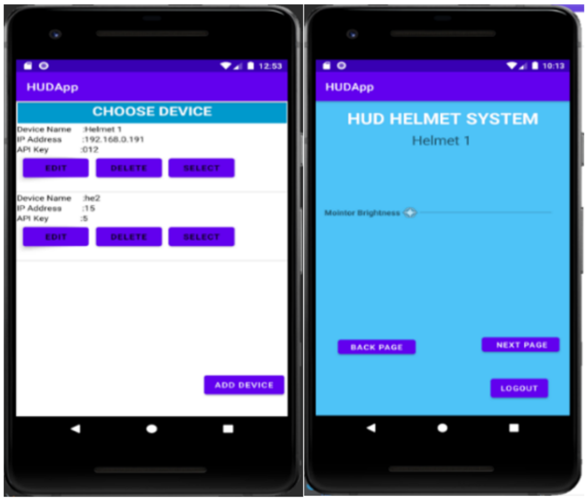

Fig. 8. LCI-HUD App.

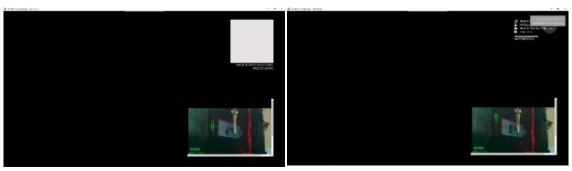

Fig. 9. LCI-HUD Different pages.

IV. Conclusion and Future Enhancement

The need for IoT devices that bikers could use daily motivated the development of the LCI-HUD. In the Asian market, HUD helmets are extremely expensive and of inferior quality. Additionally, helmets that come with HUDs rarely offer much functionality. The HUD Helmet System application, which has a working prototype included in the LCI-HUD, integrates the Raspberry Pi (Python and JavaScript) with Android Studio. The LCI-HUD was intended to be modular since it is easy to swap out any section with an improved version in the future that incorporates third-party APIs to enable user customization. The LCI-HUD is easily upgraded or replaced by users, due to its modular design, which keeps it up to date with new technologies. Furthermore, the incorporation of third-party APIs creates countless opportunities for user customization and feature growth beyond what is initially provided. When comparing the software features and safety offerings in cars equipped with Google's Android Auto and Apple's CarPlay, it becomes evident that there is significant potential for future growth in integrating similar technologies for motorcycles. Currently, there is a noticeable gap in support for these features and safety measures tailored specifically for bikers. Overall, the LCI-HUD's modular design and integration with third-party APIs make it a versatile and future-proof solution for users looking to customize their experience. Using the ability to easily upgrade and replace components, users can stay ahead of the curve in technological advancements and this reduces e-waste as it promotes backward compatibility and enhancing existing helmet to retrofit with LCI-HUD.

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