ISSN 2618-1568 Vol. 6, Issue 5: 7-13, DOI: 10.25236/FAR.2024.060502

Research on the design of intelligent riding helmet system

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Abstract: *Since country has issued a "one helmet and one area" policy, the demand for non-motorized vehicle helmets has increased significantly, and the intelligence and digitalisation of wearing equipment have become an inevitable trend. This project takes the smart riding helmet as the entry point. From the physiological, safety, and psychological needs, integrated steering lights, brake induction lights, camera records, positioning detection, honeycomb structure buffer layer, Bluetooth audio, speed itinerary monitoring function and other functions. Dedicated to protecting the security of users and providing a lightweight and comfortable experience, it is also committed to making the appearance details more in line with people's cognitive preferences. Further, it is hoped to increase the usability and user experience of the helmet through the non-disturbing humanised intelligent interaction mode during riding, facilitate communication with peers, provide all-round protection and intelligent experience for riders, and help users to have a safer, cheerful and eclectic riding trip.*

Keywords: *Cycling helmets; smart product design; wearable design; road safety; interaction design*

1. Introduction

As one of the vulnerable road users, head injury of cyclists accounts for the largest proportion of collision accidents and is the leading cause of death[1,2]. Wearing a helmet has proven to be one of the most effective ways to prevent injuries and fatalities from two-wheeled vehicles, and it can significantly reduce medical expenses[3]. To improve the safety of non-motorized drivers, the country has issued the "One Helmet Belt" policy initiative, and the demand for helmets has increased rapidly.

At the same time, under the tide of the wisdom age, the intelligence of wearable devices has become a trend. At the end of 2023, the International Data Corporation (IDC) released the Chinese wearable market in the third quarter of 2023, a year-on-year increase of 7.5% and a global increase of 2.6%year - -year, setting the highest shipment record in the past two years. The amount will increase further in 2024. It is expected that equipment shipments will reach 559.7 billion units, an increase of 10.5%over 2023.

In this context, it is crucial to design smart helmets that meet non-motorised drivers' physiological safety and psychological needs, provide all-around protection and convenience, and enhance usability and user experience.

2. Market analysis of cycling helmets

With the development of intelligent technology, helmet products began to add intelligent attributes to essential protection, such as has landed Helmetphone smart helmets with features such as Bluetooth calls, collision detection, brake taillights and so on. However, the majority of the sales in the market today are still traditional riding helmets that can only play a basic protective role. At the same time, the C-end user demands for safety and intelligent technology habits continue to transfer to the B-end, and the existing smart helmet functions are not perfect; there are still some functional deficiencies and vacancies so that it can not fully meet the needs of cycling, in these contexts also spawned a more professional helmet intelligent demand, the application of smart helmets is still rising potential.

This article mainly divides the demand for smart helmets today into the following three aspects:

2.1 Physiological safety

The safety and comfort of a riding helmet are crucial and fundamental.

ISSN 2618-1568 Vol. 6, Issue 5: 7-13, DOI: 10.25236/FAR.2024.060502

Security is divided into two types: active and passive: active protection refers to the rider's ability to protect and prevent an accident that may occur in advance. For example, it can be equipped with a warning system and reflective device for the helmet to improve the alertness of the surrounding environment and effectively reduce the possibility of accidents. In terms of passive protection, when an accident occurs, the helmet should protect the rider's head from serious injury and reduce the consequences of the accident by absorbing the impact energy and buffering the impact force. At the same time, an excellent man-machine comfort design can improve the comfort and cycling experience of riders wearing helmets, including wearing and reasonable experience in use, thereby encouraging more people to use the helmet and comprehensively improving the level of cycling.

In summary, the role of riding helmets in the three aspects of active protection, passive protection and human-machine comfort is indispensable. It is a vital safety equipment in the process of cycling.

2.2 Psychological aspect

(1) Easy to accept the appearance of the details: the product needs to satisfy people's needs for the appearance of cycling, whether a daily commuter or cycling enthusiast can try to meet the user's perception and aesthetics. In this regard, existing helmet styles are already very diverse, including the classic half-mask, full-mask, urban and competitive models. The smart cycling helmet designed in this paper aims to present a sense of lightweight fashion adapting to daily and leisure cycling use scenarios.

.In addition, the design of the smart cycling helmet in this paper hopes to combine functionality and decoration. In addition to the basic safety and protection functions, the helmet can integrate intelligent systems, LED lights, reflective strips and other decorative elements. For example, LED lights can be cleverly integrated into the surface or side of the helmet, which can not only improve the safety and riding experience of night riding but also increase the fashionable sense of the helmet.

(2) Expand social, service and other attributes: we can take the helmet as a starting point to improve the entire riding experience, such as developing a unique social platform or application so that riders can more easily share riding experience, routes, photos, etc., and interact with other riders. This platform can be combined with the data of the smart helmet, and the helmet can also record the riding process and provide personalised training plans or riding suggestions.

Also, the experience process of the smart riding helmet should be considered. From purchase to use, the whole process should be simple and smooth, and users can easily understand the functions and operation methods of the helmet. Moreover, after-sales service is a vital link, and users should be able to quickly obtain maintenance and upgrade services to ensure long-term stable operation of the product.

2.3 Interaction

As a smart wearable product, the interaction experience of the product is significant. Especially during the cycling process, interaction that conforms to the user's psychological cognition and habit is an indispensable part of the user experience.

(1) Intuitive information display and real-time feedback and reminder: the information display on the helmet should be intuitive and adopt a straightforward design, such as the use of simple symbols or colours to represent different states and information, which is convenient for riders and passers-by to understand quickly; And helmets should be able to provide users with feedback and warnings in a timely manner to help users quickly discover and respond to potential danger in the cycling process.

(2) Natural interaction: Users should be able to control the function of the helmet through simple and natural interaction during the riding process without affecting the stability and safety of the riding. For example, technologies such as voice commands or gesture recognition can be adapted to allow users to easily control the functions of the helmet without distracting themselves.

(3) Personalized setting options: The interactive interface of the helmet may support personalised setting options, allowing users to customise according to their preferences and needs.

3. Design idea

In response to the above needs, our design idea is to develop an intelligent riding helmet system, which includes a smart helmet, a simple controller and a supporting mobile phone application. The smart helmet will integrate various functions such as security, control, and entertainment and cooperate with

ISSN 2618-1568 Vol. 6, Issue 5: 7-13, DOI: 10.25236/FAR.2024.060502

the controller and mobile phone applications. The three parties complement each other to provide riders with a comprehensive, intelligent experience.

The design function idea is shown in Figure. 1; The system unfolds the function based on the helmet; the main helmet part has the most important safety protection and navigation, shooting and other functions; at the same time, the user can use the controller fixed on the handlebar to carry out the operation, including steering, voice control, answering the phone and so on. Users can check the helmet's status, intelligent control and operation through the mobile phone App, as well as view riding routes, share their lives and interact with friends and family, which further enhances the social experience and sense of achievement of riding.

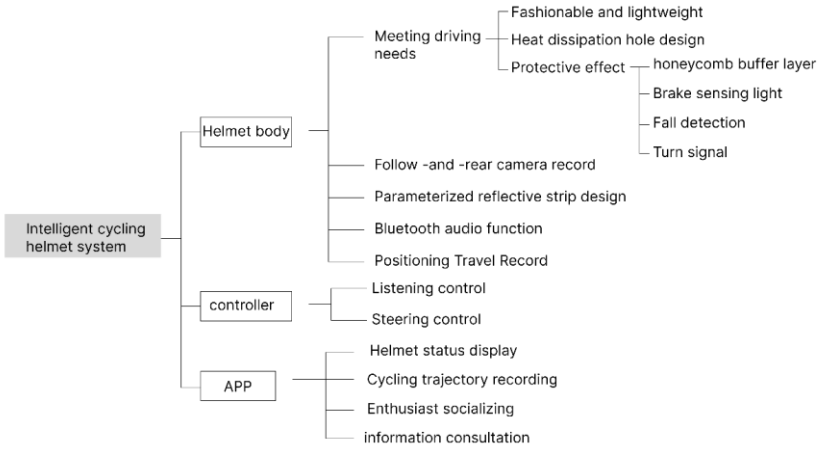

Figure 1: Frame diagram of design ideas

Through the above design ideas and objectives, our smart helmet system aims to provide riders with a safe, convenient and personalised riding experience and become an intelligent companion and guarantee during the riding process.

4. Design scheme

4.1 Appearance Design

Today's helmets are generally divided into full helmet, 3/4 safety helmet, half helmet and uncovered helmet according to the use scene and crowd. This design scheme adopts a half helmet because it only covers the upper part of the head helmet. Compared with other types of helmets, the half helmet is the most lightweight and breathable. Its advantages are wide field of vision, good ventilation performance, light weight, easy operation, diverse styles, can better observe the traffic conditions around, and reduce the head sweat and stuffy feeling, reduce the burden of the head and neck, reduce fatigue, improve the comfortof riding.

The smart cycling helmet designed in this paper aims to present a light and stylish feel with a lightweight. This means that the design should be simple and smooth, with a lightweight shape that matches the dynamic nature of cycling. The helmet's appearance can adopt modern design elements, such as smooth shape, clean lines and fashionable colour combinations, to highlight the sense of technology and fashion.

At the same time, the design scheme includes placing a textured reflective strip on the front brim of the helmet, creating a concave and convex volume appearance with a woven scattered pattern. This serves as a warning signal while also reflecting a sense of freedom. The rear tail light features an irregular gravel shape, symbolising non-rigidity and individuality. When braking is detected, it flashes to alert pedestrians and vehicles behind.; The controller controls steering information, and the lightning pattern side light displays streamers to remind others while echoing the feeling of lightning.

4.2 Helmet function design

4.2.1 Basic functions

(1) Honeycomb structure buffer layer

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Compared to the traditional EPS cushioning layer, advancements in materials and technology have created an opportunity to enhance the cushioning layer in critical helmet areas. Numerous studies have demonstrated that the honeycomb structure offers the highest crush strength-to-weight ratio. However, traditional foam moulding techniques have limited their potential. The combination of 3D printing technology and elastomeric materials such as TPU, widely used for its excellent load-bearing capacity, impact resistance, and shock absorption properties in 3D printing, makes incorporating a honeycomb structure into helmet components feasible. This interconnected honeycomb shape revolutionises the conventional EPS cushioning construction from both material and structural perspectives while reducing material usage and overall weight.

3D printing technology for helmet liners has long been employed in helmet production to achieve lightweight designs that are impossible with traditional manufacturing methods. Additionally, it allows for customised, individualised helmet products tailored for ultimate comfort[4]. Furthermore, compared to conventional EPS structures, the ventilation effect of a honeycomb structure significantly improves overall airflow within the helmet without requiring specific air deflector slots carved into the EPS. Moreover, due to its structural characteristics and texture relationship during impacts, it triggers deformation, which enhances energy absorption capabilities—KRIOS's honeycomb cushioning material can increase energy absorption efficiency by approximately 30% compared to general EPS materials.

(2) Steering and brake light display

As mentioned in 4.1 Appearance Design, the design of the brake-sensing tail light and turn signal light combines decoration and functionality: the brake-sensing tail light adopts acceleration sensors, automatically senses the braking action of the vehicle and lights up the brake light to remind the rear vehicles to pay attention to slowing down and avoiding; the turn signal light is controlled by the controller fixed on the handlebar, and the corresponding side of the light will turn on the running light mode when it receives a signal and can be changed to the general display mode to warn other pedestrians when there is no signal to turn.

(3) Fall detection and alarm system

The three-axis acceleration sensor that detects the brake information can also be used to detect human falls [5]. When the fall information is detected, the helmet can make a distress sound and send a distress message to the emergency contact person reserved by the user in the program. After a collision, if the rider is less affected and can move, he can press the button on the device; then the helmet will return to normal and inform the emergency contact that he is safe.[6]

4.2.2 Social functions

(1) Location and travel record

By integrating the GPS module and corresponding sensors on the helmet and connecting it with a smartphone, the positioning and trip recording data can be transmitted to the mobile phone application for saving and analysing, and the real-time tracking function can be realised through the mobile phone application at the same time.

The positioning function can record the rider's position in real-time, helping them to be found and rescued more quickly in emergencies and improving cycling safety; if the rider loses the helmet inadvertently, the positioning function can help them locate the helmet accurately and retrieve the helmet; for the cycling enthusiasts, the recording of cycling routes, speeds, mileage, and other information can also provide them with cycling data analysis and review, which can help them optimise their cycling plan and improve the riding experience. ‘

(2)Navigation and audio functions

By integrating a Bluetooth module and audio device into the helmet, riders can receive navigation information directly through the helmet's speakers, enhancing safety by avoiding potential traffic hazards associated with wearing headphones. This feature also offers various navigation modes and route options for different riding scenarios. Additionally, the integrated audio system allows for music playback, providing riders with an enjoyable musical experience and contributing to a more relaxed riding process.

(3) Front and rear camera recording

Cameras are installed on the front and rear of the helmet. The driving road conditions are saved to the TF card in real-time, which can not only monitor the riding process but also be an effective means to safeguard interests in the event of traffic accidents[7]. It can also provide riders with a full range of riding

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records, sharing their riding experience with others or for self-review.

4.3 App design

Data transmission and control are achieved by connecting the integrated and user-friendly mobile phone application with the helmet, and then the helmet functions are systematised. The functional framework of the application is shown in Figure 2 and is designed to be divided into three sections: Ride, Discover and Personal, each with the following functions:

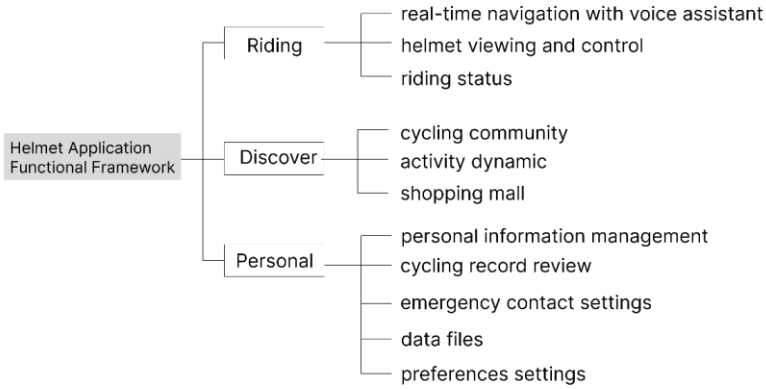

Figure 2: Helmet Application Functional Framework

(1) Riding

The riding section includes real-time navigation with voice assistant, helmet viewing and control, riding status and other modules: the helmet connects to the mobile phone program through the Bluetooth technology mentioned above and provides real-time map information through audio and voice interaction with the helmet; viewing and control module allows users to view the status of the smart helmet in real-time, including power, connection status, safety warning and other information to ensure riding safety, and can also be used for device tracking and recovery; The cycling status module displays the relevant data of the current cycling, route planning and road conditions, surrounding attractions and other information.

(2) Discovery

The discovery section includes the cycling community, activity dynamic, shopping mall and other major modules. In the cycling community, users can post to share cycling routes, attractions, experiences, and moods. They can also team up with other cyclists to ride, communicate, and interact to enhance the social experience and interaction of cycling. The activity dynamic module can browse the activities and competition dynamics in cycling communities or clubs, participate in online and offline cycling activities, and expand the cycling circle. The shopping mall offers brand-related product sales and personalised customisation of products like helmets.

(3) Personal

The personal section includes personal information management, cycling record review, emergency contact settings, data files, preferences settings, and other modules to provide private cycling assistance.

Through the extended functions of these applications, the cycling section will be more complete, providing cycling enthusiasts with a full range of cycling experiences and services, improving the convenience, safety and fun of cycling, and further promoting the social experience and sense of achievement of cycling.

4.4 Technical and Feasibility Analysis

(1) Chip technology

As one of the core technologies of wearable smart products, Chip technology determines the regular operation and execution speed of product functions. The internal space of helmet products is limited, so the chip size must also be small and compact. System on Chip (SoC) integrates multiple functions into a

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single chip, covering the processor, memory, sensor interface, communication interface, power management and other functions, thus realising highly integrated and compact design, which can shorten the development cycle and reduce the cost, power consumption and space occupation. It is an essential technological means to realise multi-functional and high-performance intelligent wearable devices.

(2) Sensor technology

Navigation and audio module requires high-performance GPS module and microphone sensors, as well as a unique audio processor chip for real-time navigation and voice control; camera shooting module requires to pick a high-definition camera sensor suitable for the size of the helmet, and equipped with a high-performance image processor chip to assure that the shooting effect is clear and steady; brake sensing module and the drop detection and alert system demands accelerometers, The brake sensing module and clip detection with alert system need accelerometer, gyroscope or inertial measurement unit (IMU) integrated with both, which is used to detect the acceleration change, angle, attitude change and movement state of the helmet, and the chip will regulate the brake taillamp to light up when the brake action is computed from these data, when the acceleration exceeds the threshold, the system will determine the fall event, trigger the alarm and transmit the alert information to the contact person, so as to better the safety of cycling.

(3) Bluetooth control function

Data transmission methods can be categorised into wired and wireless. Wireless transmission technologies include Bluetooth technology, 5G technology and millimetre wave radar. Among them, Bluetooth is a short-range wireless communication technology that enables transmitting data or signals between different devices without needing a physical media connection. The main features of Bluetooth technology are low power consumption, low cost, easy integration, support for complex networks and smart connectivity. The implementation of the Bluetooth control function requires an efficient Bluetooth module for communicating with the controller and mobile phone, which may need to support Bluetooth Low Energy (BLE) to reduce power consumption and control the operation of the Bluetooth module through an integrated chip to process the received commands and control the functions of the helmet.

(4) Battery technology

Battery technology is one of the indispensable technologies in wearable intelligent products, taking into account safety and battery life. Today's battery types are primarily lithium-ion batteries, which can also be equipped with battery management systems to monitor battery parameters, while charge management systems and protection devices are responsible for managing the charging process and protecting the battery from overcharge, over-discharge, short circuit and other dangers. Charging methods can include USB charging or more convenient wireless charging. Wireless charging technology uses the principle of electromagnetic induction to transmit electrical energy from the charger to the receiver inside the device, thereby charging the device.

In summary, the chips, sensors, and electronic components required to realise the intelligent rriding helmet are diverse and must be selected and designed according to each function's requirements and performance needs, as well as accurately processed and assembled. Through reasonable combination and layout, it can ensure the stable and reliable operation of the intelligent cycling helmet and provide a high-quality use experience.

5. Summary

This study delves into a novel approach to cycling in the era of smart wearable devices based on an analysis of daily usage and the requirements of cycling enthusiasts. It systematically designs solutions to enhance the experience of smart wearable devices for cyclists. This paper explores in-depth the physiological, psychological and interactive needs of the cycling scene. It proposes solutions in appearance and functional design, combining functionality and decoration to give the helmet special features, providing a new way for cycling and helping the user to have a safer, more enjoyable, and more eclectic cycling experience.

References

[1] Aare M, Holst H. Injuries from motorcycle and moped crashes in Sweden from 1987 to 1999[J]. Injury control and safety promotion, 2003, 10(3): 131-138.

ISSN 2618-1568 Vol. 6, Issue 5: 7-13, DOI: 10.25236/FAR.2024.060502

[2] Matsui Y, Oikawa S, Hitosugi M. Features of fatal injuries in older cyclists in vehicle–bicycle accidents in Japan[J]. Traffic Injury Prevention, 2018, 19(1): 60-65.
[3] Shu Xiaoyong, LI Chengxiang, Sun Wen. Research on Customized Design of Riding Helmet Based on Parameterization [J]. Design, 2022, 35 (04): 132-135.
[4] Jiang Miaowen, Chen Jimin, Yan Jianzhuo. Research on Personalization and Lightweight of helmet for Winter Olympic Games based on 3D Printing Technology [J]. Applied Laser, 2017, 37(3):424-429.
[5] Wang Rong, Zhang Yun, Chen Jianxin. Design and Implementation of Human fall Detection System based on Three-axis Acceleration Sensor [J]. Journal of Computer Applications, 2012, 32(05):1450-1452+1456.
[6] Cui Wenhua, Huang Zhaoxian, Dong Jie, et al. Design and Implementation of Intelligent Riding Helmet based on Chierder CH32V307 [J]. Internet of Things Technology, 2023, 13(11):96-99+102.
[7] Mo Shaoqu, Zhang Wansheng. Application Research of Multi-function Tachograph Based on Internet of Things Technology [J]. Times Automobile, 2022,19 (1): 21-23