A Multi-functional Safety Helmet for Electric Bikes Based on Arduino

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Abstract: In the multitude of roads, safety is paramount. Riding safety is the foremost consideration for us, as electric vehicles have become a widely used mode of transportation in our daily lives. When riding electric bikes or motorcycles, helmets serve as the sole protective safety device. However, the helmets available on the market currently only serve a cushioning function and lack any additional safety warning or protection devices. Therefore, developing a smart, safety-oriented electric bike helmet holds significant importance. This project uses current helmets as a baseline, undergoing comprehensive modifications and upgrades. Utilizing the Arduino board as the driving core and incorporating eco-friendly solar power supply, the helmet enhances safety features beyond basic protection. It introduces left and right collision warnings, turn-based pedestrian safety alerts, fall alarms,and a temperature-controlled mini fan to earnestly safeguard the life safety and comfort of rider and passenger.

1. Introduction

Traffic safety is a hot issue of great concern today, with an average of one person dying every five minutes due to road accidents in China. Traffic accidents have become the second leading cause of death after diseases. This is particularly true for delivery workers riding electric bikes and motorcycles, for whom helmets are their only form of protection. Data shows that in Shanghai, a delivery worker is involved in a traffic accident resulting in injury or death every 2.5 days on average. Traffic regulations have also been further clarified, mandating the wearing of helmets while riding electric vehicls, as properly wearing a helmet can effectively reduce the death rate from traffic accidents by 60%-70%[1]. This paper starts with a safety helmet and strives to upgrade its functionality. The goal is to provide electric bike drivers with helmets that offer better safety protection and a more comfortable wearing experience.

Currently, helmets on the market often lack additional intelligent protective measures. While wearing a helmet can significantly reduce the mortality rate in accidents, it does not fundamentally reduce the occurrence of accidents. Additionally, the current level of comfort provided by helmets is inadequate, leading to excessive heat when worn in the summer and consequently making many individuals disinclined to wear them. Lastly, the field of smart helmets is still in its infancy; existing helmets lack effective safety warning measures. Therefore, I aim to create a multifunctional safety helmet similar to the passive safety devices in cars to protect riders.

2. Project Proposal

2.1 Project Exploration

2.1.1 Proposed Solutions

After reviewing the helmets currently on the market and various literatures, it has been observed that aside from their basic function of being worn, helmets rarely come equipped with safety features, and the few safety features present are not genuinely utilized. Figure 1 is the Project Background.

According to the current technology I have mastered, the possible improvements for this project include:

(1) A collision warning device, akin to the car radar, is proposed to alert drivers about vehicles

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approaching from behind, aiming to prevent collisions that occur when drivers fail to timely acknowledge the presence of oncoming traffic from the rear prior to making turns[2].

(2) Turn signaling feature: Although some electric bikes are equipped with turn signals, they are often not prominent, and many electric bikes lack this feature altogether. Therefore, I plan to add turn signals and a voice alert system for pedestrians to the helmet.

(3) Speeding alarm warning: It is widely acknowledged that speeding in automobiles poses significant dangers; however, the hazards of speeding on electric bicycles are even more severe. After all, in the event of an accident, a car provides a lot of protection to its occupants, whereas an electric bike offers no protection at all. The consequences of a rollover accident at high speed are extremely severe.

(4) Automatic defogging windshield: In cars, when the front windshield fogs up, the defrost switch can be activated to automatically eliminate the fog. Thus, the integration of this function into helmet visors is proposed.

Figure 1 Project Background

2.1.2 Function Determination

Based on the analysis and argumentation of the four safety features mentioned above, and considering the comfort of helmet wear, the following functionalities have been established for this project:

(1) Vibration motors on the corresponding side will vibrate when vehicles approach from the left or right rear, alerting the rider to be cautious.

(2) When turning is required, the rider says the direction, and the voice recognition module, upon identifying the command, activates the light strip to display the corresponding turn signal, while the speaker plays a turning reminder[3].

(3) In the event of a fall, the light strip automatically flashes blue and red lights, and the speaker emits a sound for help.

(4) After dark, the rear light automatically turns on to alert vehicles behind.

(5) A temperature-controlled fan is added, which automatically activates when the temperature is too high.

(6) A Bluetooth module pairs with the smartphone, facilitating navigation information reception for the rider.

(7) A solar panel is added to provide power to the entire device under sunlight.

2.2 Results Display

The physical project image is shown in Figure 2. This project involved 3D printing the main body of the helmet, after which all components were installed, with some components being secured using hot melt adhesive. An inner lining was added inside the helmet to enhance comfort during wear. The installation locations of the components throughout the project are shown in figure 3.

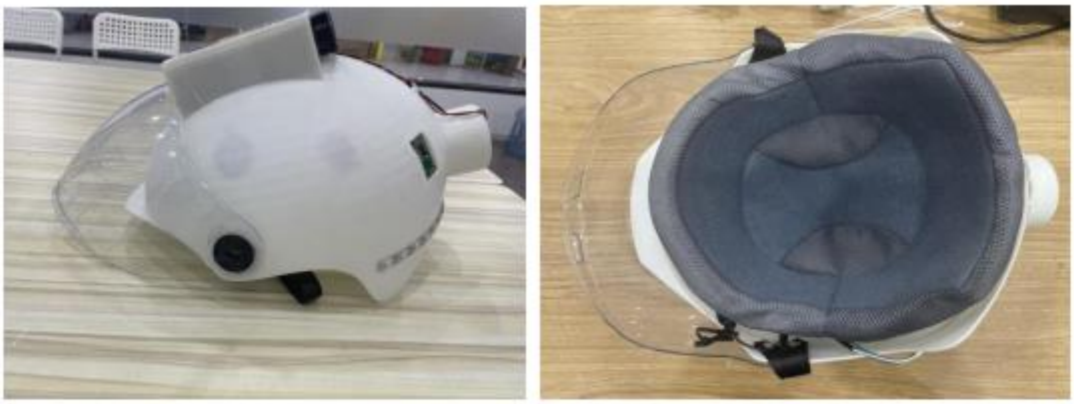

Figure 2: Physical Project Image

Figure 3: Rear View Image

3. Design Process

3.1 List of Used Components

Based on the functionality required for this project, the following materials were selected. Table 1 is the List of Components.

Table 1: List of Components

Serial No.	Name (Quantity)	Function
1	Arduino Mainboard (1)	Drives the operation of the entire program
2	Microwave Radar (2)	Detects the approach of vehicles from the left and right rear
3	RGB Light Strip (1)	Serves as turn signals and outline lights reminder
4	MP3 Module (1)	Converts built-in mp3 files into a controllable driver
5	Small Speakers (2)	One for playing alert sounds, one for playing Bluetooth navigation instructions
6	Relay (1)	Controls motor rotation
7	Gear Motor (1)	Drives the fan to rotate
8	Bluetooth Module (1)	Connects with mobile phone Bluetooth
9	Gyroscope (1)	Detects helmet movement and falls
10	Voice Recognition + Microphone (1)	Recognizes the driver's voice commands
11	Vibration Motor (2)	Alerts in different directions
12	DHT11 Temperature and Humidity Sensor (1)	Detects the helmet's internal temperature
13	Photoresistor (1)	Detects the intensity of external light
14	Solar Panel	Absorbs solar energy from the surroundings
15	18650 Battery (2)	Stores the solar energy

3.2 Circuit Diagram Design

Building upon the schematic of this project, a wiring diagram was created using drawing software to facilitate subsequent circuit connections. All components in this project require a 5V power supply, and attention must be paid to the correspondence of GVS connection pins. As illustrated, the RGB light strip is connected to the D2 port, the relay to the D4 port, and the MP3 module to the D6, D8, and D10 ports. The speaker is connected to the MP3 module, the DC motor's red wire to the 5V power supply, and the black wire through the relay's NO terminal, with the relay's COM terminal connected to the power supply's ground. The Bluetooth module is connected to the mainboard's VCC and GND. The microwave radar is connected to the D11 and D12 ports; the gyroscope to the IIC bus; the DHT11 temperature and humidity sensor to the A0 port; the photoresistor to the A1 port; vibration motors to the A2 and A3 ports; and the voice recognition module to the A4 and A5 ports, utilizing the IIC bus function.

3.3 Structural Design

After completing the schematic and circuit diagrams, the final task was to design the structural diagram. The project primarily revolves around the helmet as the base, incorporating multiple components. The ultimate goal is to create an electric bike helmet. A commercially available electric bike helmet was purchased for reference, and under the guidance of a teacher, a helmet schematic as illustrated below was designed using SolidWorks. Figure 4 is a helmet structural diagram.

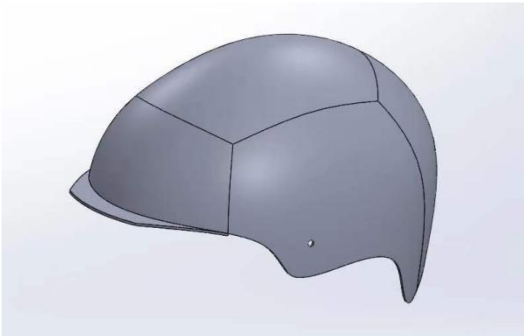

Figure 4: Structural Diagram (1)

Due to the need to incorporate an inner lining, the overall dimensions of the helmet are slightly larger than a standard helmet, specifically 230*280mm. Additionally, two small holes were left on each side to facilitate the installation of the visor. The drawing process for this part encountered several challenges, primarily due to the complexity of calculating the helmet's curvature. After trying various methods, the final helmet model was obtained as shown in figure 5.

Subsequently, it was necessary to account for the dimensions of the Arduino mainboard (80*60mm) and the MP3 module (30*30,mm), thus the dimensions of the top electronic component box were set at 120*90mm.

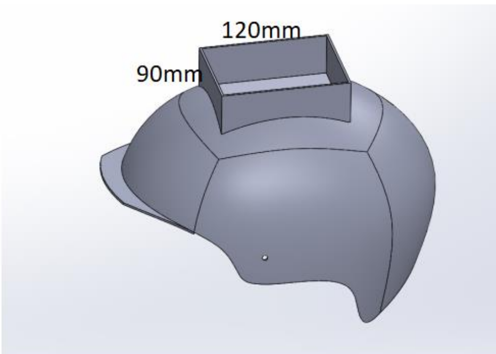

Figure 5: Structural Diagram (2)

Next, the assembly focuses on the positions of the rear fan and the microwave radar module. The fan selected is the smallest available size, with a diameter of 60mm. The microwave radar measures 50*20mm, necessitating the creation of two holes at the back.

Finally, the addition of wire routing holes and a switch completes the entire structural diagram. Figure 6 is the final structural diagram.

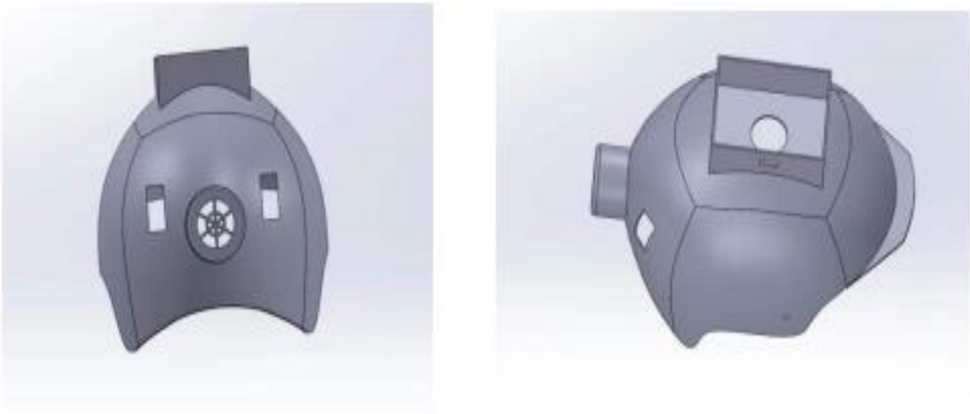

Figure 6: Structural Diagram (3)

4. Fabrication Process

4.1 Device Assembly

Utilizing the 3D structural design, the helmet was printed through Taobao. Each component was then connected and installed according to the structural and circuit diagrams. The main tools included a screwdriver, hot melt adhesive, wire strippers, and Dupont wires for the installation of various components. Additionally, with my father's assistance, a drill was used to create holes, and rivets were used to secure the visor and the elastic band for the electric bike. The fabrication process is shown in Figure 7.

Figure 7: Fabrication Process Image

4.2 Programming

After testing all the components, I assembled the entire program. The specific idea is to encapsulate each function as a function, and then put it into the master program, judge it through conditional statements, and execute the corresponding program.

5. Project Testing and Analysis

5.1 Experiment One

Figure 8: Experiment Image (1)

Figure 8 is one of the images during the experiment.

Testing Environment: Real-world road testing

Testing Purpose: To evaluate the functionality of vehicle approach warning from the left and right rear, and the turn warning to pedestrians

Testing Steps:

① To simulate a realistic electric bike riding condition, my father drove the bike while I, holding the electric helmet, sat at the back of the electric bike. Over a continuous 15-minute period, I assessed the specific vibrations of the vibration module.

② While on the road, speaking towards the helmet tested the voice module's speech recognition and its success rate.

Data is presented in the following table 2:

Table 2: Experiment 1- Data Record

Number	**Road Condition**	Number of Vibrations on the Right Side	Number of Vibrations on the Left Side	Number of Left Turn Commands	Number of Successful Recognitions	Number of Right Turn Commands	Number of Successful Recognitions
1	Residential Area Road Surface	12	10	3	3	5	5
2	Non-Motorized Lane	10	8	5	4	6	4
3	Residential Area Road Surface	13	11	3	2	5	5
4	Non-Motorized Lane	9	6	4	3	5	4

Data Analysis:

①The residential area roads, due to the many vehicles parked on both sides, resulted in frequent activations of the vibration module, leading to instances of misrecognition. On non-motorized lanes, there were issues in recognizing approaching electric bikes from behind, though car detection functioned essentially correctly.

②On residential area roads, given the lower environmental noise, the voice recognition accuracy was 100%. On non-motorized lanes, various environmental noises on the road could easily affect the accuracy of voice recognition.

③ The overall success rate of the project's functionality was above 80%, meeting the anticipated project objectives.

5.2 Experiment Two

Testing Environment: Indoor

Testing Purpose: To verify the functionality of the outline lights and fall alarm during nighttime conditions, as well as to ensure the proper operation of the fan and Bluetooth features.

Testing Steps:

①The outline light functionality was tested by turning indoor lights on and off.

②A fall scenario was simulated by vigorously shaking the helmet to observe the light warning signals.

③A hairdryer was used to blow hot air on the temperature sensor, simulating a hot and stuffy summer environment, to see if the fan worked properly.

④ The helmet's Bluetooth was connected to a smartphone to check if navigation information was displayed correctly.

Test images are shown in Figure 9.

Figure 9: Test

Experiment Analysis:

①The nighttime outline lights functioned correctly, activating when the lights were off and deactivating when the lights were on, with all detections operating normally.

②The fall alarm feature was tested by swinging back and forth, revealing that significant force was required to trigger the fall alarm condition. It may be beneficial to lower the acceleration threshold for this part.

③ Given the current winter season, a hairdryer was used to simulate a hot summer environment for testing, and the fan operated normally.

④The Bluetooth module quickly paired with a smartphone, and the voice functionality worked well.

⑤ Except for the gyroscope, which could not simulate real-life scenarios during testing, all other functionalities worked as expected.

6. Conclusion and Future Prospects

This project, utilizing 3D printing technology, has enhanced an existing helmet by adding proactive and passive safety features such as alerts for vehicles approaching from the left and right rear, pedestrian warnings during turns, fall alarm alerts, and nighttime outline lights, significantly increasing the safety of electric vehicle riders. It also prevents potential collisions with pedestrians caused by the driver's distraction. Furthermore, the addition of a cooling fan and Bluetooth navigation has increased wearer comfort and further ensured driver safety. Wearing this helmet allows us to have eyes on all sides and ears attentive to all directions while riding electric bikes. After all, as electric bikes are relatively vulnerable on the road, accidents can have serious consequences. The introduction of this helmet could certainly reduce the occurrence of accidents.

Through the fabrication of this helmet project, I have gained a deep understanding of the various potential dangers electric bike riders face on the road. It has also made me constantly remind my father to be cautious while riding his electric bike. Working on this project has allowed me to learn how to use various software and become familiar with more components. I am delighted to have been able to create this project. I hope this helmet can assist those who ride electric bikes, especially delivery riders, by providing a last line of defense for their safety and encourage drivers to be more patient. In summary, traffic safety is an issue that must always be taken seriously, and I hope everyone, whether driving, biking, or walking, pays attention to safety.

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