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Design of Turn and Brake Lights of Bicycles Using Advanced Wireless Transmission

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Bicycles usually are not equipped with electronic sensors and lighting, which are employed in motorcycles and automobiles. Therefore, it is not easy for riders to monitor the operational status of bicycles. To overcome this problem, in this study, we developed a wireless safety light system for bicycles, with a particular focus on turn and brake lights. The system is used to signal for turning, lane changing, slowing down, and stopping, which also increases the visibility and predictability of bicycles in traffic. Two ESP32 modules were adopted for Bluetooth-based wireless transmission to ensure the system's practicality and affordability. The lighting system is easy to install and maintain at a low cost. By integrating innovative technology, an affordable and cost-effective solution is offered to enhance safety for bicycle riders and other road users.

1. Introduction

Bicycles are a popular mode of transportation in many cities and countries owing to their environmentally friendly nature and zero carbon emissions, being ideal for short-distance commuting. In addition, riding bicycles is convenient and cost-effective, playing a crucial role in urban transportation. However, safety issues present significant challenges for bicycle riders on the road. They are particularly vulnerable to collisions with vehicles or motorcycles, especially during nighttime or under conditions of low visibility owing to their smaller size and the lack of sensors and a lighting system commonly used in vehicles and motorcycles. This inability to effectively communicate with other drivers increases the likelihood of accidents when changing lanes, turning, or reducing speed.

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Increasing the visibility and recognizability of bicycles is important, especially under conditions of poor visibility. Therefore, a lighting system similar to those in motorcycles and automobiles was developed in this study.(1) Other studies that also aim to reduce bicycle accidents have predominantly focused on the development of smart helmets integrated with IoT technologies.(2) The system incorporates multiple sensors to prevent and detect accidents, and can transmit the rider's location to emergency medical services in real time upon the occurrence of an accident. In contrast, we focused on improving the visibility and recognizability of the bicycle, thereby enabling other road users to be more easily aware of the bicycle while it is moving. Although both studies share the common objective of enhancing cycling safety, the other study primarily addresses rider protection, whereas our study emphasizes vehicle-based safety enhancements.

In this study, we equipped bicycles with a basic lighting system that includes two red lights to signal turning and rectangular brake lights. When a rider turns, changes lanes, slows down, and stops, other road users can see the corresponding lights. The rider can simply press a touch switch near the handlebar to signal turns or apply the brake lever to signal slowing down or stopping. The display module at the rear of the bicycle shows signals to warn road users. The lighting system significantly enhances the safety of bicycles and effectively avoids collisions with other vehicles. The simple, user-friendly, and intuitive lighting system does not necessitate complicated installation or setup. By utilizing Bluetooth low energy (BLE), complicated wiring and maintenance are unnecessary.(3,4) Through further study, wireless transmission technologies integrated into IoT can be employed in the lighting system of the bicycle for the easier use and maintenance of the lighting system.(5,6)

2. Lighting System

2.1 Hardware

To increase the visibility of the turn signal and the brake light, we used the MAX7219 8 × 8 LED matrix display (Fig. 1).(7,8) For the buttons for lighting the turn signal, a TTP223 touch sensor (Fig. 2) was used, whereas for the brake light, a pressure sensor (Fig. 3) was adopted in the brake lever. The sensors and lights were connected to the control board and the power supply. The buttons were placed near the handlebar for easy use. The turn signal was displayed as an arrow on the MAX7219 matrix display installed near the rear reflector of the bicycle.(9) To avoid interference, the least interfered channel was selected by the automatic frequency hopping feature in the Bluetooth communication protocol. As the lighting system was installed on the bicycle, a portable external battery pack was used to power the control board and the MAX7219 matrix display. The lighting system was made waterproof using an enclosure such as a plastic corrugated board or an acrylic board to prevent moisture or dust from entering and damaging the electronic components and circuit board. The material of the enclosure withstands high temperatures and impacts to prevent any physical damage.

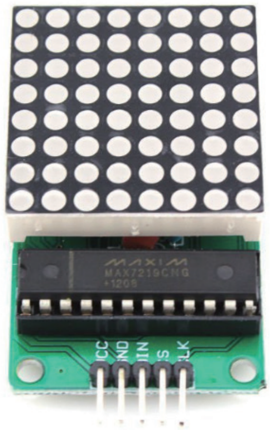


Fig. 1. (Color online) MAX7219 matrix display.

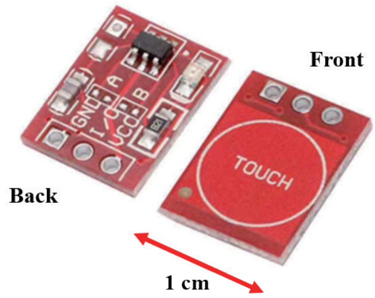


Fig. 2. (Color online) Front and back of TTP223 touch sensor.

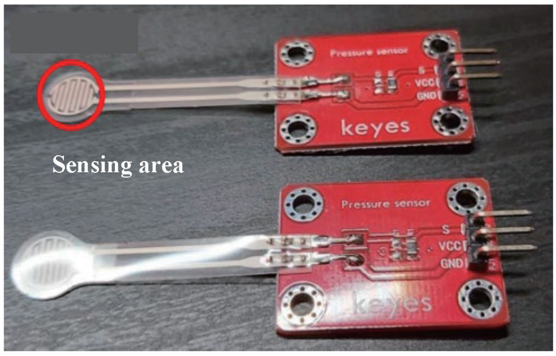


Fig. 3. (Color online) Pressure sensor and its components.

2.2 Operation

When the TTP223 touch sensor began operating by toggling the button to control the direction lights, a stack data structure was used to store the most recent turn signal. Errors when activating different turn signals continuously were prevented by the stack data structure (Fig. 4). When new data were stored, the old data were temporarily overwritten to prevent different signals from appearing simultaneously.[10–13] For example, if the left turn signal was activated and then the right turn signal was turned on, the left turn signal was erased and the right turn signal started flashing. If the right turn signal was turned off, the left turn signal resumed flashing. The stack structure was used to display the latest (top) data state to display the last signal.

The brake light was operated using the pressure sensor (Fig. 3). Whether the brake light turned on was determined by the sensed resistance. When the pressure exceeded a threshold, the brake light was activated. The pressure was determined by the force applied to the brake lever.

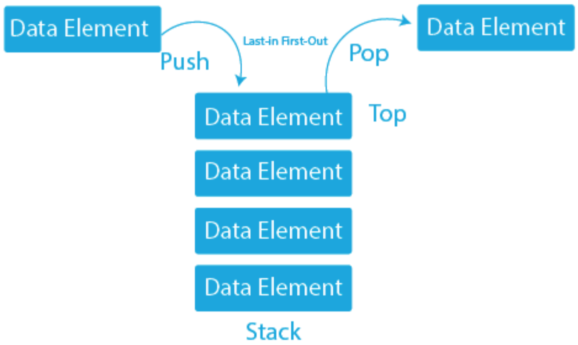


Fig. 4. (Color online) Stack data structure used in lighting system of bicycles.

When the pressure applied to the brake lever was sufficient to cause the bicycle to decelerate, the brake light was activated. According to piezoresistivity, the greater the pressure applied to the sensor, the lower the resistance (Fig. 5). Pressure arranges the molecules of the sensing material to increase conductivity or reduce resistance. Conversely, the lighter the pressure, the higher the resistance.

An ESP32 development board was used as the control board of the lighting system (Fig. 6).(14) BLE was adopted for signal transmission between components (Fig. 7). BLE is a wireless communication protocol of low power, short range, and low data transmission rate and is designed for personal area network technology. The development board comprised the server for system control and Bluetooth for transmitting signals using a universally unique identifier (UUID). When UUID receives the signal, the client generates the corresponding signal on the basis of preset commands.

3. Test Results and Discussion

The lighting system was installed at the front and rear of the bicycle, occupying minimal space and volume. Figure 8(a) shows the activation of the brake light when the brake lever is pressed. The pressure sensor was attached to the brake lever as shown in Fig. 8(b). In the lighting system, the external battery pack was placed on the bicycle frame [Fig. 8(c)]. As the lighting system was powered by an external battery pack, it is necessary to monitor if the pack is sufficiently charged. However, as BLE and LED were used, the energy consumption of the lighting system was low. A fully charged 10,000 mAh battery pack provided sufficient power to the lighting system for up to 10 h.

In operating the lighting system, three buttons were used to signal the left and right turns, and hazard light (Fig. 9). When pressing a button, a corresponding light signal was displayed, and to turn it off, the button was pressed again. If two or more buttons were pressed, the signal was determined by the last button pressed. There were small indicator lights below the buttons to show which button was pressed. When the indicator light is on, it indicates that the button is inactive and no light signal will be displayed. Conversely, when the indicator light is off, it indicates that the button is active and the corresponding light signal is shown.(15)

(a) (b)

Fig. 5. (Color online) Operation of pressure sensor based on piezoresistive effect. (a) Internal structure of sensor (the orange line represents the circuitry and the purple line represents the piezoresistive material). (b) Pressure decreases the resistance of the piezoresistor.

Fig. 6. (Color online) ESP32 board. (The red circle is the reset button).

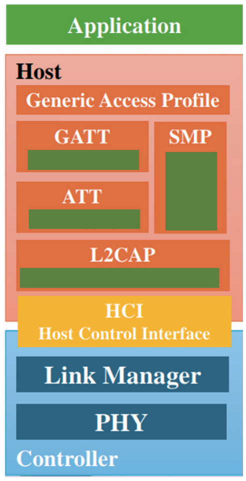
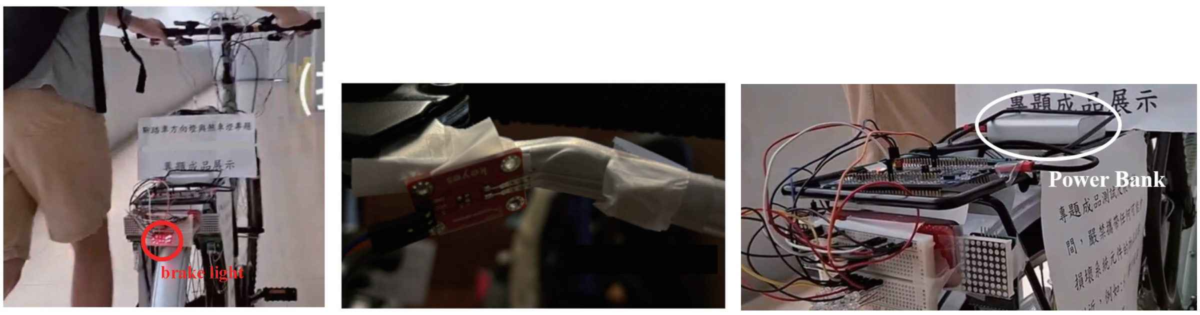


Fig. 7. (Color online) Architecture of BLE.



(a) (b) (c)

Fig. 8. (Color online) Operation of brake light and installations of pressure sensor and external battery pack. (a) Activation of brake light with pressed brake lever. (b) Pressure sensor attached to brake lever. (c) External battery pack mounted on frame of bicycle.

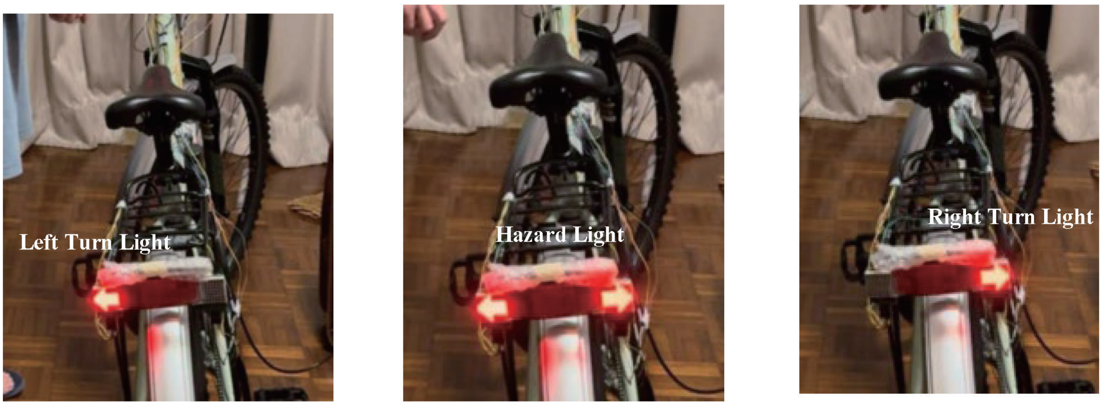


Fig. 9. (Color online) Operation of left and right turns, and hazard light.

5. Conclusions

To prevent bicycle accidents on the road, a lighting system similar to those of vehicles is required for bicycles. In this study, we developed a lighting system that displays turn signals, deceleration, and a complete stop of the bicycle using BLE, a MAX7219 matrix display, a pressure sensor, a touch sensor, and an ESP32 development board. The lighting system is powered by an external battery pack. The test result of the system indicated that the turn signals and brake light operated effectively without any confusions and errors. Although a prototype system has been fabricated and tested, it establishes the basic principles of a bicycle safety system for road use and suggests its potential widespread adoption to prevent collisions with vehicles and other road users. In addition to turn signals and brake light, numerous applications can be integrated, such as a blind spot monitoring system and a rear approach alert system. These additional systems can significantly enhance the safety of riding a bicycle on the road.

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