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Power Assistance System of Bicycle Based on HT66F2390 Microcontroller

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In this study, a low-cost bicycle power assistance device, which can operate without altering the frame structure of the bicycle, is proposed. It does not require disassembling the tires or the wheel frame, making it an easily installable add-on system. Compared with other existing electric-assist bicycles or retrofit kits, the scalability and hardware compatibility of the device developed in this study are relatively higher. The system primarily relies on a microcontroller unit (MCU) core, with HT66F2390 as the main controller, integrating a brushless electric motor for power drive, a Hall sensor to detect sprocket speed, MCU switches, a magnet disk, and a 350 W lithium battery. First, without modifying the bicycle frame, a fixture for securing the power-assist motor is designed to attach the motor to the bottom edge of the frame. In this study, we recorded the power of several riders traveling the same approximately 5 km route twice, before and after modification. Before modification, the one-way riding power was 200 W, and after modification, it increased to 230 W, representing an increase of approximately 20%. These data indicate that the system assists riders in conserving energy.

1. Introduction

Existing complete systems include electric-assist bicycles, but these types of vehicle are relatively expensive and not widely adopted for mass commuting. Our aim is to install a power-assist system on standard geared bicycles, which are more commonly used for commuting. Currently, there are two main retrofitting methods: one involves directly replacing the front or rear wheel with a motorized wheel, controlled by a switch to adjust its power output; the other involves an external rear wheel drum motor, which utilizes friction between the drum and the tire to provide power assistance to the rear wheel. This system follows the latter approach.

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2. Literature Review

2.1 Taiwan bicycle users in the past five years

At present, the population of bicycle riders in Taiwan is substantial. According to data from the Taiwan Bicycle Association, there are approximately twenty three million people in Taiwan who ride bicycles regularly. A 2019 survey indicated that about 25% of Taiwanese people ride a bicycle at least once a week. In major cities such as Taipei, Kaohsiung, and Taichung, public bicycle rental systems (such as YouBike) are frequently used, demonstrating the high acceptance of bicycle commuting among urban residents. The Taiwanese government and related organizations are also continuously promoting bicycle culture by building more bike lanes and organizing various cycling events, further increasing the prevalence of cycling.

2.2 Existing electric-assist bicycles

Taiwan currently offers a variety of brands and models of electric-assist bicycles, including well-known names such as Gogoro, the public rental system YouBike, Xiaomi (Mi Electric Scooter), Birdy's foldable designs, and local and international brands such as Giant and Merida. These bicycles come with different power ratings, battery life spans, and design styles to cater to various riding needs and personal preferences. Electric-assist bicycles, while having advanced features, are significantly more expensive than regular bicycles.

2.3 External power assist

External-power-assist bicycles refer to designs where an external-power-assist system is added to the base bicycle.[1] The main types include electric-assist conversion kits, rear wheel drum motors, and other electric-assist devices installed on the frame. These designs allow regular bicycles to gain electric assistance capabilities without altering the original frame structure, enhancing convenience and functionality for riders. The kit used in this study is a homemade external power motor kit, as shown in Fig. 1. Its advantages include compatibility

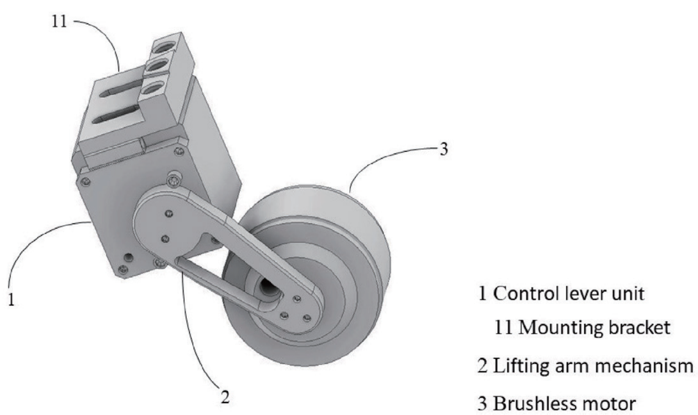

Fig. 1. Power motor design diagram.

with most bicycle models, relative affordability, and the ability to enhance power output based on the rider's pedaling speed.

2.4 Microcontroller unit (MCU) controls and different power assistance levels

The operation of all motor engines is controlled by an MCU, and the system includes Hall sensors for reading the values of the rider's pedal strokes. These values are processed and controlled within the MCU. The MCU is programmed with a default setting of three power segments, enabling assistance at varying power levels based on the rider's output during cycling.

3. Methodology

In this study, we aimed to retrofit a standard bicycle with a power system consisting primarily of a control lever unit and a brushless motor. During operation, the control unit lifts the motor to engage with the tire, whereas during shutdown, the lever returns to its original position, aiming to prevent wheel slippage on wet surfaces.(2) Figure 1 illustrates the conceptual design, showing the bike's installation position. The Hall sensor is mounted on the bicycle's bottom bracket, with a magnetic disk installed inside the central pedal. This setup is depicted in Figs. 2 and 3.(3–5)

3.1 Research system architecture

The system uses HT66F2390 as the core microcontroller chip, which provides functions such as timer, I/O, external interrupts, and Universal Asynchronous Receiver-Transmitter.(6) It integrates the Hall sensor module and brushless motor inside. The Hall sensor, installed next to the bicycle's bottom bracket with an external disk, rotates with the pedals. The MCU reads values from the Hall sensor and determines the current revolutions per minute on the basis of preset gear levels. In this study, we plan to install a set of Hall sensors and a set of electric motors

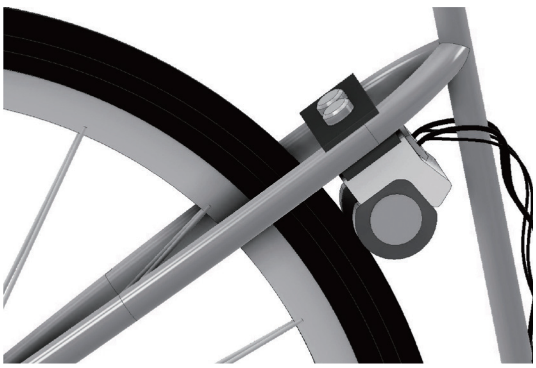

Fig. 2. Installation method.

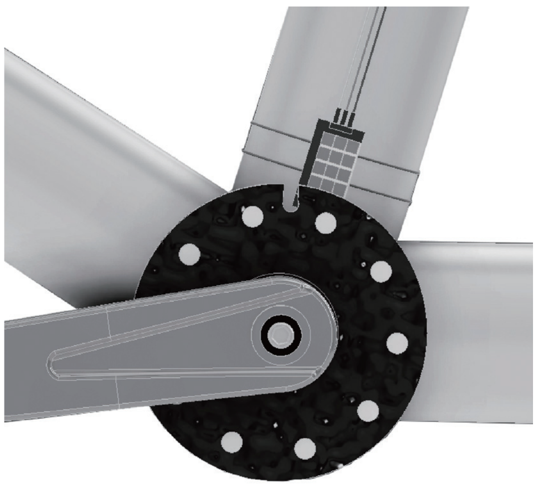

Fig. 3. Hall sensor and sensing magnetic disk.

on the bicycle. Riders can activate the power-assist motor by pedaling, with higher pedal speeds resulting in increased motor power. This setup significantly reduces leg exertion. The system's hardware architecture is illustrated in Fig. 4.

3.2 Research system firmware architecture

The firmware control principle of the system operates as illustrated in Fig. 5. The Hall sensors detect the movement of the pedals, read the speed of the wheel, and transmit these signals to the microcontroller for computation.(7) The system divides the gears into three levels. On the basis of the detected speed, the microcontroller determines the appropriate gear and provides the corresponding power assistance.

3.3 Different power assistance levels

Because statistically, professional cyclists average 350 W of power while riding a 15 km route, our hardware for this study also operates at a maximum power of 350 W. Cyclists need to feel the power assistance, starting with higher assistance initially. On the basis of actual riding experiences, the first power segment is set to 140 W, the second segment at 2/3 of full power, approximately 240 W, and the third segment at full power, 350 W (Table 1).

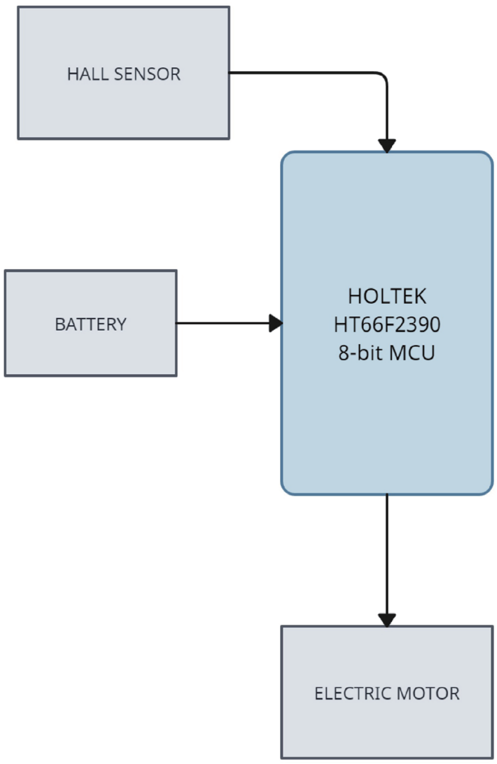

Fig. 4. (Color online) Functional flow for warning system.

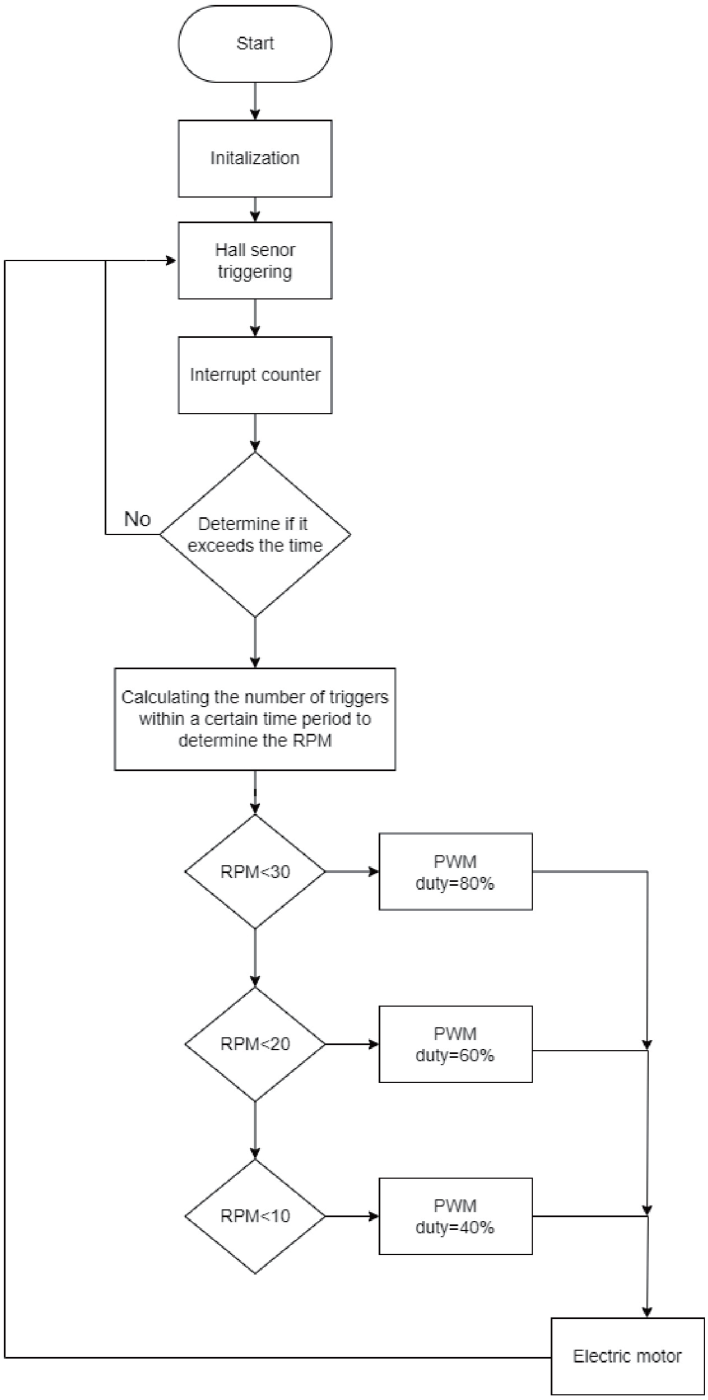

Fig. 5. Firmware architecture diagram.

Table 1
Level and output.

Level	Output (W)
1	140
2	240
3	350

4. Experiments

4.1 Riding on a flat section for the experiment

A 25-year-old youth conducted round-trip tests on a straight, flat 2 km and 4 km stretch of riverside road, as shown in Figs. 6–9. Riding times with and without the power system under the same riding conditions were compared to estimate the cycling average speed. In Table 2, the result of distance with power shows average time and speed.

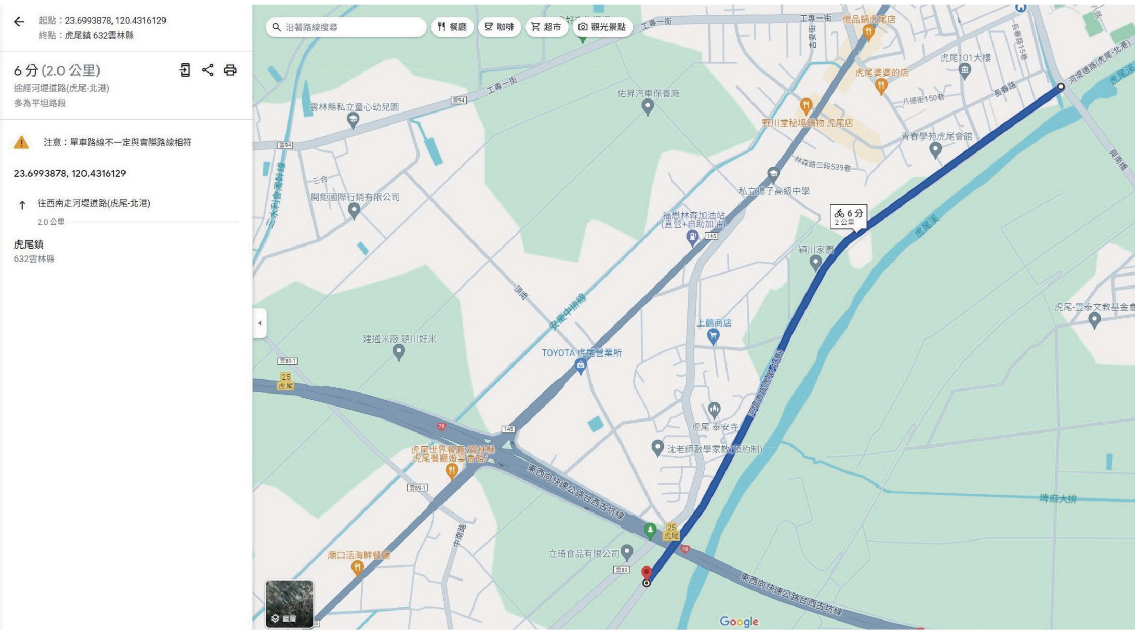

Fig. 6. (Color online) 2 km section.

Fig. 7. (Color online) 2 km altitude of approximately 25 m.

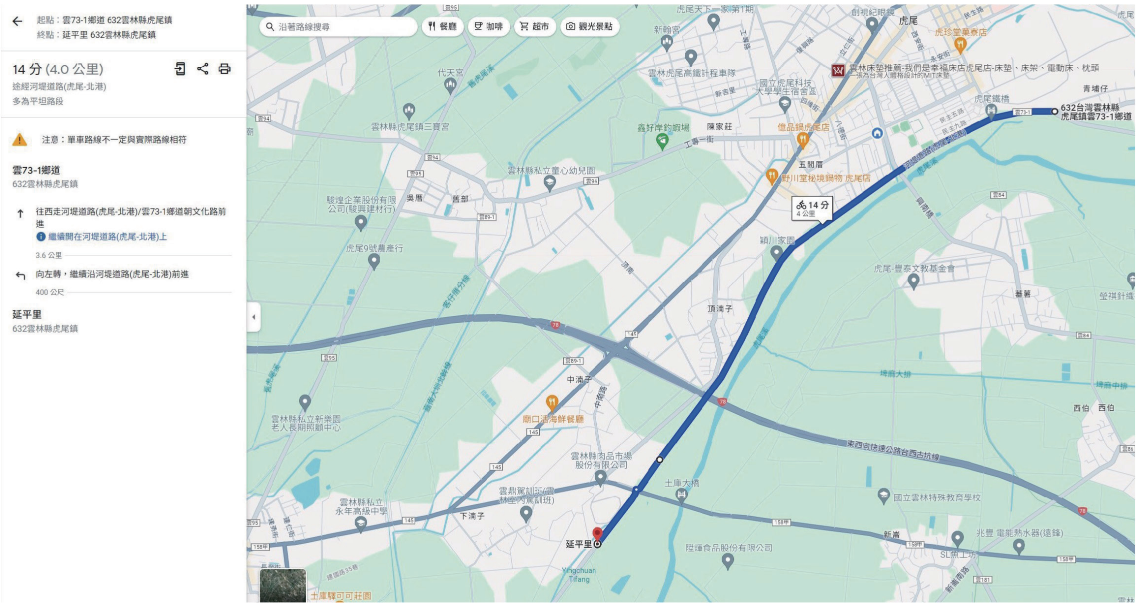

Fig. 8. (Color online) 4 km section.

Fig. 9. (Color online) 4 km altitude of approximately 25 m.

Table 2
Average time and speed.

System	Distance (km)	Average time (s)	Average speed (m/s)
yes	2	196	10.2
no	2	242.5	8.25
yes	4	485	8.25
no	4	660	6.06

4.2 Riding on an uphill section for the experiment

The second experiment took place in a hilly area with moderate slopes, as shown in Figs. 10–13, with an elevation gain of approximately 80 m. The testing distances were 2 and 3

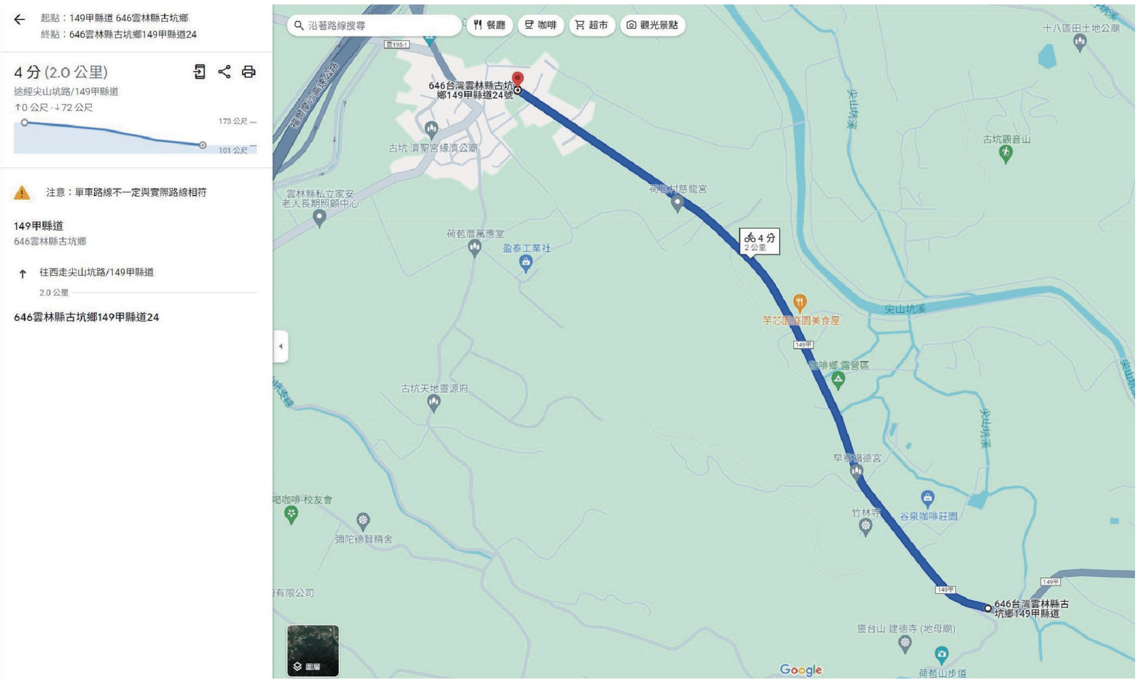

Fig. 10. (Color online) 2 km section.

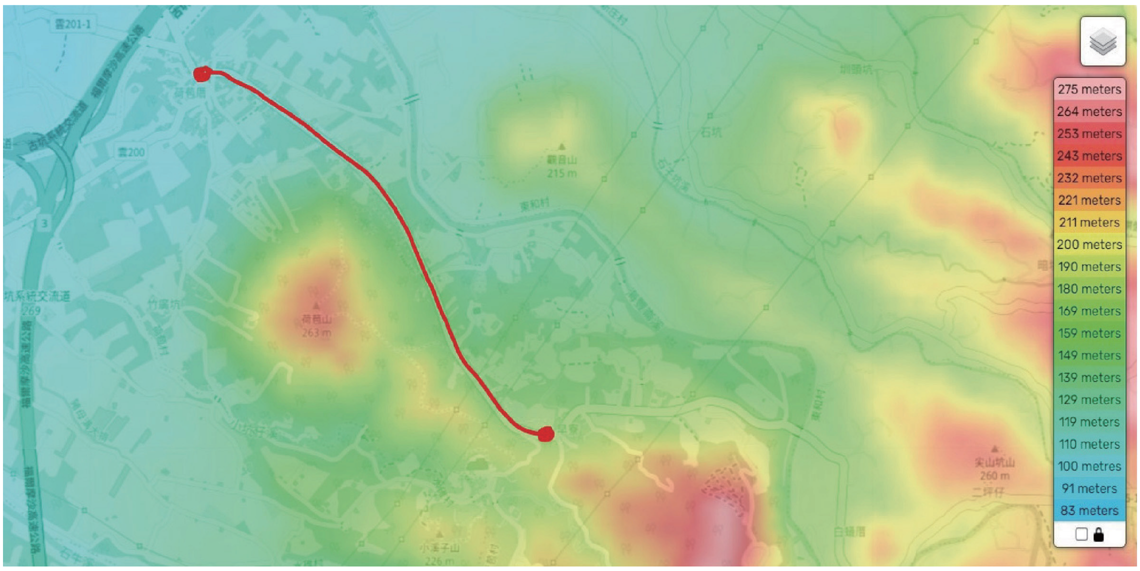

Fig. 11. (Color online) 2 km altitude with elevation gain of approximately 80 m.

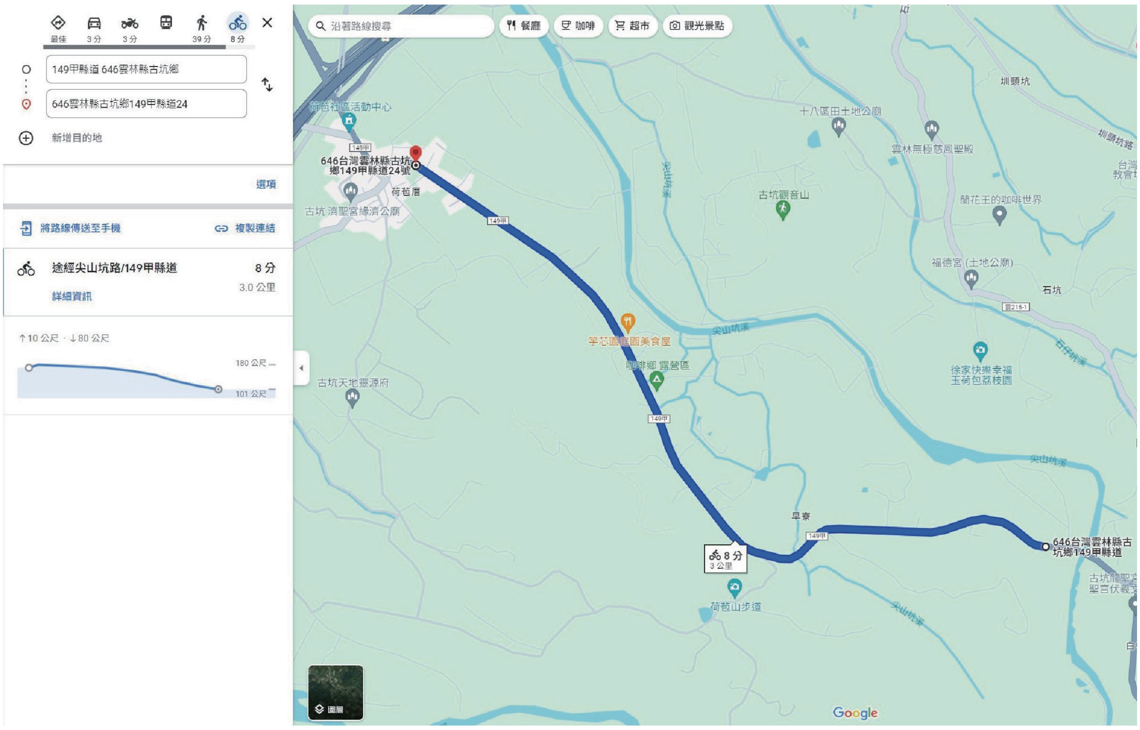

Fig. 12. (Color online) 3 km section.

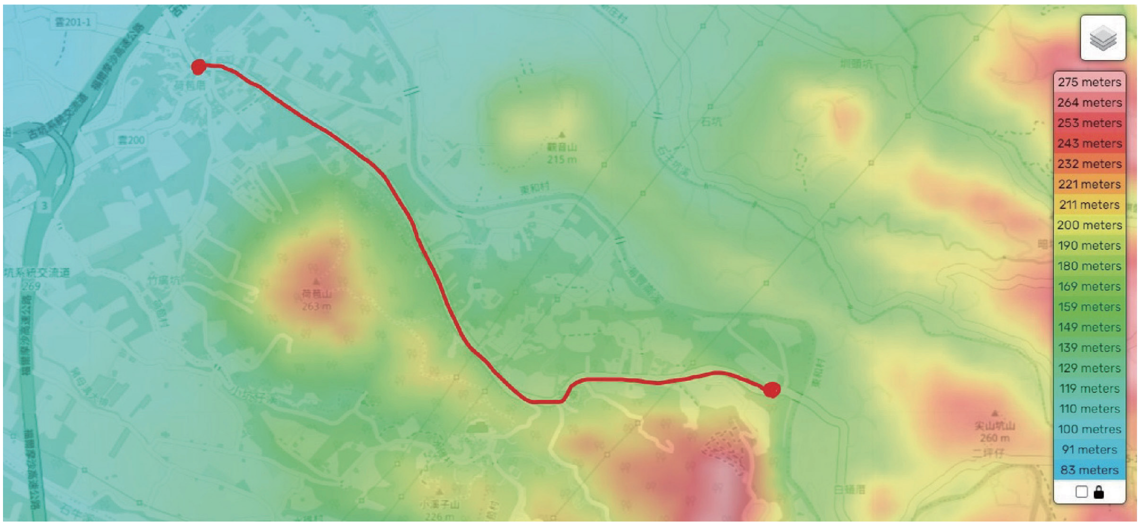

Fig. 13. (Color online) 3 km altitude with elevation gain of approximately 80 m.

km. A 30-year-old youth conducted round-trip tests under the same riding conditions to compare the riding times determined with and without the power system, and the cycling average speed was estimated on the basis of the calculated riding times. In Table 3, the result of distance with power shows average time and speed.

Table 3
Average time and speed.

System	Distance (km)	Average time (s)	Average speed (m/s)
yes	2	233	8.5
no	2	302.5	6.61
yes	3	484	6.2
no	3	580	5.17

5. Conclusions

In this study, we utilized a brushless motor and Hall sensor to implement a power-assist system for bicycles. The sensor was installed on the side of the bicycle pedal to measure the rider's pedaling speed. Through an MCU, predefined gear settings were applied to adjust the motor's power output, providing notable assistance to the rider. In subsequent experimental data, where this system was deployed and tested on the same distance and route conditions, the results showed a reduction in total time by approximately 20%. This reduction indicates that the system effectively provides assistance.

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