Electric Bike Monitoring and Controlling System Based on Internet of Things

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***Abstract*—Electric bicycles are now widely available in the Indonesian market. Most electric bicycles have not been integrated with smartphones. As a result, they are currently unable to be monitored or controlled remotely. In this study, an internet of things (IoT)-based monitoring and control system for electric bicycles was developed. An ESP32-based microcontroller was used as an IoT device to measure distance traveled with a GPS sensor by applying the Haversine method, measuring bicycle speed, designing a bicycle safety system, and designing a calorie measurement system when a bicycle was pedaled. The SIM800L module was used as a communication device, where this module was capable of establishing internet communication over a 2G network. The electric bicycle controller was modified to be integrated with the ESP32 for electric bicycle propulsion using a BLDC type motor with a voltage of 36 V. Raspberry Pi was used as a web server for data storage and processing. The metabolic equivalent of task (MET) method calculated calories burned. The monitoring and controlling of electric bicycles were carried out by building an Android smartphone-based application using the Kodular application. The map service feature was based on OpenStreetMap. This application can turn on and off the electric bicycle remotely, adjust the speed gear position, adjust the speed, turn on the alarm, track the last location, track location history, and perform calorie measurements. The control process can be done by pressing buttons and voice commands in Indonesian. This application was tested using the black box method with 100% successful results and a time delay of 8.82 s. Calorie measurement accuracy was 94.24% compared to calorie measuring equipment on the market. Speed control has linearity with an R^2 of 0.9984.**

***Keywords*—Electric Bike, ESP32, Speed Control, Internet of Things, Android Application.**

I. INTRODUCTION

Bicycles are a personal means of transportation currently in great demand by urban communities because they are environmentally friendly and efficient to ride in heavy traffic. During the COVID-19 pandemic, the number of demands for bicycles rose by 17%-19% [1].

Electric bicycles are now widely available in the Indonesian market. Some are imported from China, such as Yahonta and Tiger. However, there are also original domestically produced electric bicycles, such as the Selis, Xelimo, and Betrix. The trend of using electric bicycles in the future will grow rapidly, along with the development of electric cars. Most electric bicycles sold today are not yet integrated with smartphones, so they cannot be monitored and controlled remotely.

Research on remote monitoring of electric bicycles is still not widely found. Currently, the available research is limited to the electric bicycle design [2]. In a study conducting consumer research, it was found that respondents had a relatively high interest in electric bicycle. In addition, respondents took into consideration the specifications when buying electric bicycles. Furthermore, the predominantly studied object is about regulating the motor speed on an electric bicycle.

Electric bicycles on the market can be operated in manual mode, pedaled like a regular bicycle and using an electric motor as a propulsion. The potential target market for electric bicycles is school children. With this remote monitoring system, parents will be able to monitor the child's position, monitor the speed of the bicycle used by the child, and even can remotely control the maximum speed of the bicycle. In addition, for adults, bicycles have become part of a healthy lifestyle. One of the goals of cycling is to burn calories. Currently, electric bikes on the market have not been able to display the number of calories burned when the bike is used. The utilized solution is to use third-party applications.

An Android-based app for measuring calories on mountain bikes has been developed before [3]. In calorie measurement, the employed parameters are bicycle speed, mileage, and weight. The energy required to pedal a bike in uphill conditions, straight roads, and descents is undoubtedly different, although the generated speed is the same. This condition results in inaccuracies in calorie measurements.

In addition, previous studies have developed measurements of the electric bicycle motor speed using force sensors and electromyography (EMG) [4]. Electric bicycle speed control methods have also been developed using the self-tuning PI parameter method and fuzzy logic methods [5].

Research on the current electric bike safety system is limited. Currently, the most widely developed safety system design on the bike is on motorcycles. The use of GPS sensors on motorcycles has been developed before; however, in the study, GPS was only used to show the motorcycle's location [6]. In fact, this sensor can be used in mileage measurements. Research on motorbike battery voltage measurement has also been done before [7], but the study still displays data directly and has not been able to perform remote monitoring. Furthermore, a study on the safety system on motorcycles that have been developed has the disadvantage that when the security system works, the system is unable to notify motorcycle owners [8]. From the studies mentioned earlier, no research was developed up to the remote monitoring stage based on the internet of things (IoT).

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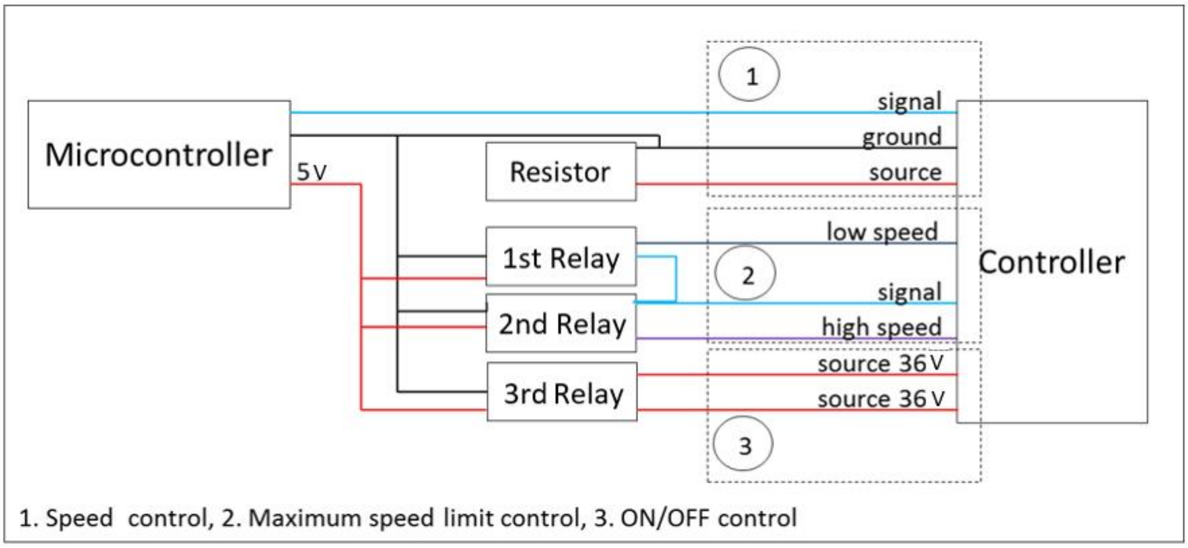


Fig. 1 Modification to the controller.

This paper develops an IoT-based electric bicycle monitoring and control system based on the foregoing. The ESP32-based microcontroller is used as an IoT device to measure distance traveled with GPS sensors, bicycle speed and is also used as an electric bicycle security system device. At the same time, the SIM800L module is used as a communication device. Raspberry Pi is used as a web server for data storage and processing. An Android smartphone-based application called "GO-WES Pro" is developed to remotely monitor and control electric bicycles' ON/OFF conditions and speed.

II. Electric Bicycle System

Electric bicycles are a subcategory of electric vehicles developed from traditional bicycles. While traditional bikes are driven only by their pedals, electric bikes combine batteries and electric motors to aid movement. In addition to the bike itself, the electric bike consists of many components. The components are described as follows [9].

1) Batteries and Chargers: This part is often known as a battery or accumulator, which is the electrical energy source that drives the motor on an electric bike. The battery used in this study is a lithium-ion model battery with a specification of 36 V 10 Ah.

2) Motor: A motor is a device on an electric bicycle that converts electrical energy into motion energy. The motor used in this study was a BLDC type DC motor with a power of 350 W.

3) Controller: The controller serves to control the speed of the electric bike. The controller specification used was a controller 36 V 350 W, following the specifications of the motor and battery. In this paper, the controller is modified by a DC relay addition to the connector for engine ignition, the DC relay addition to the speed setting connector, the DC relay addition to the braking connector, and the voltage source modification for the speed setting of the microcontroller. The performed controller modifications are shown in Fig. 1.

4) Display Panel: This panel is usually an LCD layer displaying the electric bike condition.

5) Throttle Handle: The throttle handle has two types of variations, i.e., the pull handle model and the thumb throttle model.

III. Distance Measurement from GPS

GPS is a global coordinate system that can be used to determine the longitude, latitude, and altitude of objects located anywhere on the planet. GPS can be an efficient choice to obtain real-time and automatic spatial data [10].

Latitude and longitude coordinates are most commonly used to define a location on a map. Latitude is a line which connects the east and west sides of the world between the north and south poles. The 0° latitude is also known as the equator. On the contrary, longitude refers to the line which connects the north and south poles of the earth. Suppose a straight line is drawn between two locations, the latitude and longitude coordinates can be used as variables to determine the distance between them [11].

This paper uses a Neo 06M brand GPS sensor connected to a microcontroller. The microcontroller sends longitude, latitude, and altitude measurement data to the web server. The data is then processed with the PHP language to determine the distance traveled based on the difference in coordinates before and after.

A comparison of methods to determine distance based on longitude and latitude coordinates was carried out in a study [12]. The compared methods were Euclidean, Haversine, and Manhattan methods. The obtained results indicate that the most accurate method is the Haversine method. Therefore, in this paper, the Haversine method is implemented in the PHP language.

The Haversine method is a technique for determining the distance between two places on the earth based on the length of a straight line connecting them, taking into account the earth's

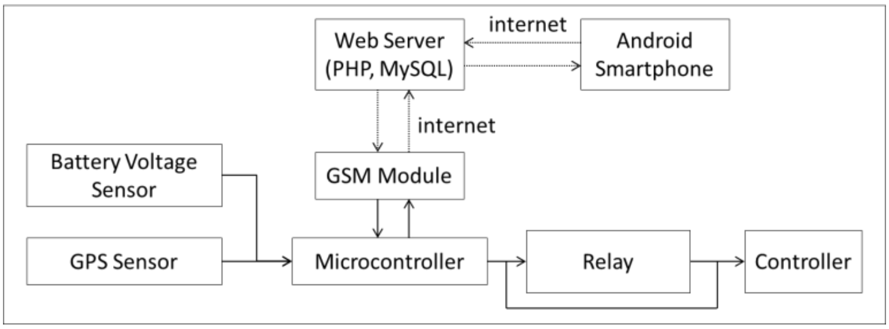


Fig. 2 General overview of the system.

TABLE I
RELATIONSHIP OF SPEED WITH MET VALUES

Speed Indicator	MET	MET per Minute
< 16 km/h	4.2	0.07
16 – 19 km/h	6.0	0.10
19.01 – 22 km/h	7.8	0.13
22.01 – 26 km/h	10.2	0.17
26.01 – 30 km/h	12.0	0.20
> 30 km/h	16.2	0.27

curvature [12]. The formula for the Haversine method is as follows.

$$a = sin^2\left(\frac{\Delta lat}{2}\right) + \cos(lat_1) \times \cos(lat_2) \times sin^2\left(\frac{\Delta long}{2}\right) \quad (1)$$

$$d = 2r \times arcsin\left(\sqrt{a}\right) \quad (2)$$

where

d = distance
r = earth radius
Δlat = latitude change
$\Delta long$ = longitude change.

IV. CALORIE BURNED MEASUREMENT

A calorie is a unit of energy, while Metabolic Equivalent of Task (MET) refers to the number of calories (cal) consumed per minute by an organism or human while performing a task. The value of 1 MET is the amount of energy absorbed by an individual or creature at rest. In addition, 1 MET is equivalent to 3.5 ml of oxygen per minute per kg of body weight during metabolic activity in the body [13]. The greater the intensity of physical activity, the greater the body's need for oxygen and MET. The correlation between increased physical activity and MET is shown in Table I. At the same time, to calculate the number of calories burned during exercise, it is used (3) [14].

$$EC = \frac{MET \times 7.7 \times \left({BB}/{2.2}\right)}{200} \times t \quad (3)$$

where

EC = calories burned (cal)
MET = metabolic equivalent of task
BB = body mass (kg)
t = time(min).

Calculation of calories burned will be implemented in the PHP language. Both methods will be compared with measurements taken with calorie measuring devices currently available on the market. The method with the best accuracy will be implemented in the system.

V. SYSTEM DESIGN

The design of this application is generally divided into two parts, namely hardware system design and software system design. The design of the hardware system includes the design of an electric bicycle system and a microcontroller system for IoT devices. On the other hand, the software design includes designing a database and designing a Kodular-based Android application.

A. Internet of Things System Design

In general, the employed control block diagram is shown in Fig. 2. The details of the correlation between the microcontroller and the electric bicycle controller are shown in Fig. 1.

In this paper, the employed microcontroller is ESP32, and the GSM module is SIM800L, employing a TTGO T-CALL board. The ESP32 and GSM SIM800L modules are integrated into this board. The ESP32based microcontroller is chosen because it has a serial port and a Wi-Fi module. ESP32 reads voltage, latitude, longitude, and altitude data from sensors then sends it to a MySQL database.

This communication process uses the GET protocol. A PHP language links ESP32 and MySQL database. The algorithm for monitoring the electric bicycle system is shown in Fig. 3. This algorithm is implemented in the PHP language.

B. Application Design

The method employed in designing the "GO-WES Pro" application is a unified modeling language (UML). One of the UML that can be used is the use case diagram. It serves to describe the process flow in the application, as shown in Fig. 4.

From Fig. 4, it can be seen that there are four main features in the application, namely "Realtime Control", "Access History", "Realtime Monitoring", and "User Profile". The user profile relates to the calorie calculation process, in addition to mileage data. In history access, there are several features, including accessing location history, mileage history, and battery voltage history. Each of these functions is implemented in an Android application.

The conducted programming method began with creating a user interface in the Kodular application and continued with

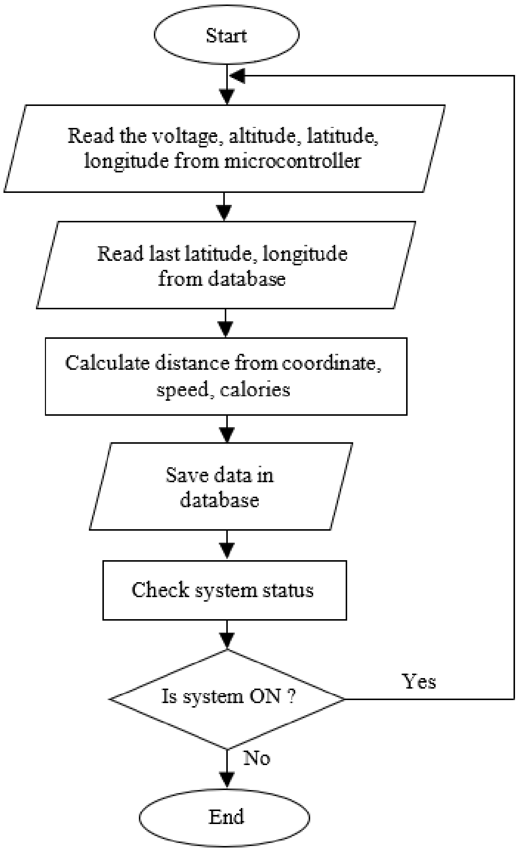


Fig. 3 Electric bicycle system monitoring algorithm.

creating program code using block code in the Kodular application.

VI. Discussion

A. Calorie Burned Measurement

This study began with comparing the calorie calculation method with the MET method, referring to (3), and comparing it with smart band/smartwatch brands sold on the market, namely Garmin 45 and Oase WS-01. In previous studies, comparisons were not made with existing tools on the market; therefore, the accuracy of the employed calorie measurement was unknown [3], [14]. The test was carried out by passing a predetermined location with a distance of about 1.1 km. The respondent in this test was a man weighing 70 kg. The results of the calories burned measurement are shown in Table II.

Table II shows that the MET method has a measurement error rate of 5.76% or an accuracy of 94.24% compared to calorie measuring devices existing on the market. This measurement error rate is still relatively high. Hence, it is necessary to make improvements in further research.

Several studies applying the MET method have errors in applying the calculation formula as in (3). In [3], the calorie calculation formula is different, which only considers weight, MET value, and time. There is no multiplier and divisor formula used in that study. In addition, in research [13], the factor coefficient in the caloric formula of 7.7 should be used if the mass is in lb. When mass was in kg, the employed coefficient was 3.5, which was 7.7 divided by 2.2 (conversion factor from lb. to kg).

TABLE II
COMPARISON OF CALORIE BURNED CALCULATIONS

Test	**MET Method**	**Smart Band Measurement**			**Error**
		Oase WS-01	***Garmin 45***	***Average***	
1	43	45	46	45.5	5.49%
2	37	35	40	37.5	1.33%
3	44	45	52	48.5	9.28%
4	38	36	42	39.0	2.56%
5	39	40	45	42.5	8.24%
6	40	37	44	40.5	1.23%
7	24	25	29	27.0	11.11%
8	29	30	33	31.5	7.94%
9	37	38	40	39.0	5.13%
10	36	37	39	38.0	5.26%
Average					5.76%

B. Android Application Testing

Black box testing is a type of software testing focusing on software functional requirements [14]. This test aims to determine the function of each element on each page in the program. From the results of the performed test, as in Table III, there are a total of seven pages, and the application is 100% as expected.

C. Travel History Tracking

One of the excellent features of the “GO-WES Pro” is that the application can display location history, as shown in Fig. 5(a). The implemented method in making travel routes was to convert the latitude, longitude, and elevation data from the MySQL database into a file with GPS Exchange (GPX) format using the phpGPX library. The phpGPX library is an open-source project accessible with the GitHub service. Then, the GPX file was integrated with OpenStreetMap (OSM). OSM is one of the map service providers such as Google Maps. OSM is an open-source and free project.

In [15], cycling routes were also converted into the GPX format. This research differs from previous studies in that the GPX data was obtained directly from the Strava application and then processed to determine the optimal route. The utilized map application was Google Maps. In addition, when compared to previous research [16], this study has several advantages. The previous research was only able to display the last location; it was unable to display the route that had been taken [16].

D. Electric Bike Monitoring

As in the previous study [16], the “GO-WES Pro” application can also track the latest location based on latitude and longitude data. In addition, a GPS device for vehicle tracking has also been developed, with tracking results displayed on a map based on latitude and longitude [17]. Besides being able to display battery voltage, speed, and coordinates in writing or maps, this application has another advantage, i.e., the ability to perform geotagging processes, which have not been found in previous studies.

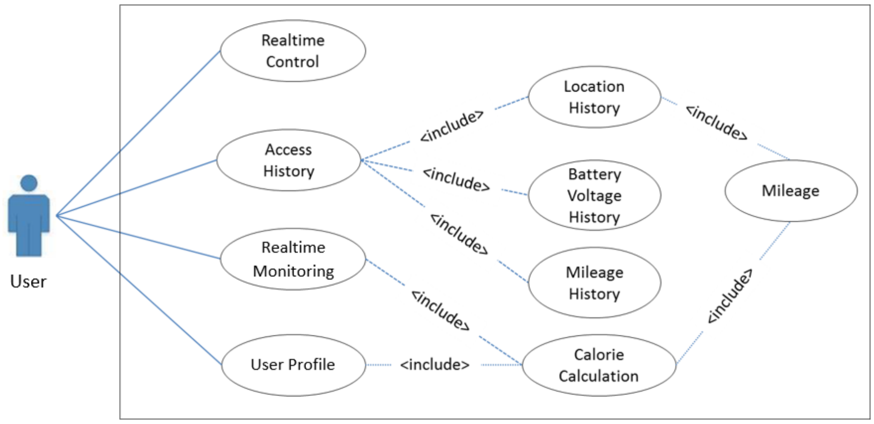


Fig. 4 Use case diagram of an Android application.

TABLE III
BLACK BOX TESTING OF ANDROID APPLICATION

Test	Test Description	Result
1	Login screen: - Entering the appropriate user and password - Entering the wrong user and password	OK
2	Register screen: - Registering with complete data - Registering with incomplete data	OK
3	Profile screen: - Viewing user profile - Changing user profile	OK
4	Monitoring screen: - Displaying real-time position with the location change and battery voltage	OK
5	Control screen: - Making changes at the press of a button. - Making changes with voice-activated commands via buttons. - Making changes with voice-activated commands by bringing the hand closer to the front camera.	OK
6	Location history screen: - Performing location tracking with an appropriate date - Tracking the location with an incorrect date	OK
7	History screen: - Performing location tracking with an appropriate date - Tracking the location with an incorrect date	OK

Geotagging is a method used to convert data from location coordinates to the address of a location. In the “GO-WES Pro” application, the geotagging process is carried out using OSM services, as in the previous process. The performed algorithm in the PHP program is to read the latitude and longitude from the MySQL database, then perform the geotagging process with OSM integration with the output in the form of a file in JSON format. Afterwards, the address file is read from the JSON file and displayed in the “GO-WES Pro” application, as shown in Fig. 5 (b).

Another study also discussed an electric bicycle battery speed monitoring and voltage [18]. This study performed voltage measurements using a power sensor, and speed measurements were performed using a rotary encoder. The measurement results were displayed on the screen mounted on the electric bicycle. Compared to that research, in this research, a voltage sensor connected to a voltage divider circuit for voltage measurement was used. At the same time, the speed measurement was calculated based on distance measurements using the previous Haversine method divided by the time difference.

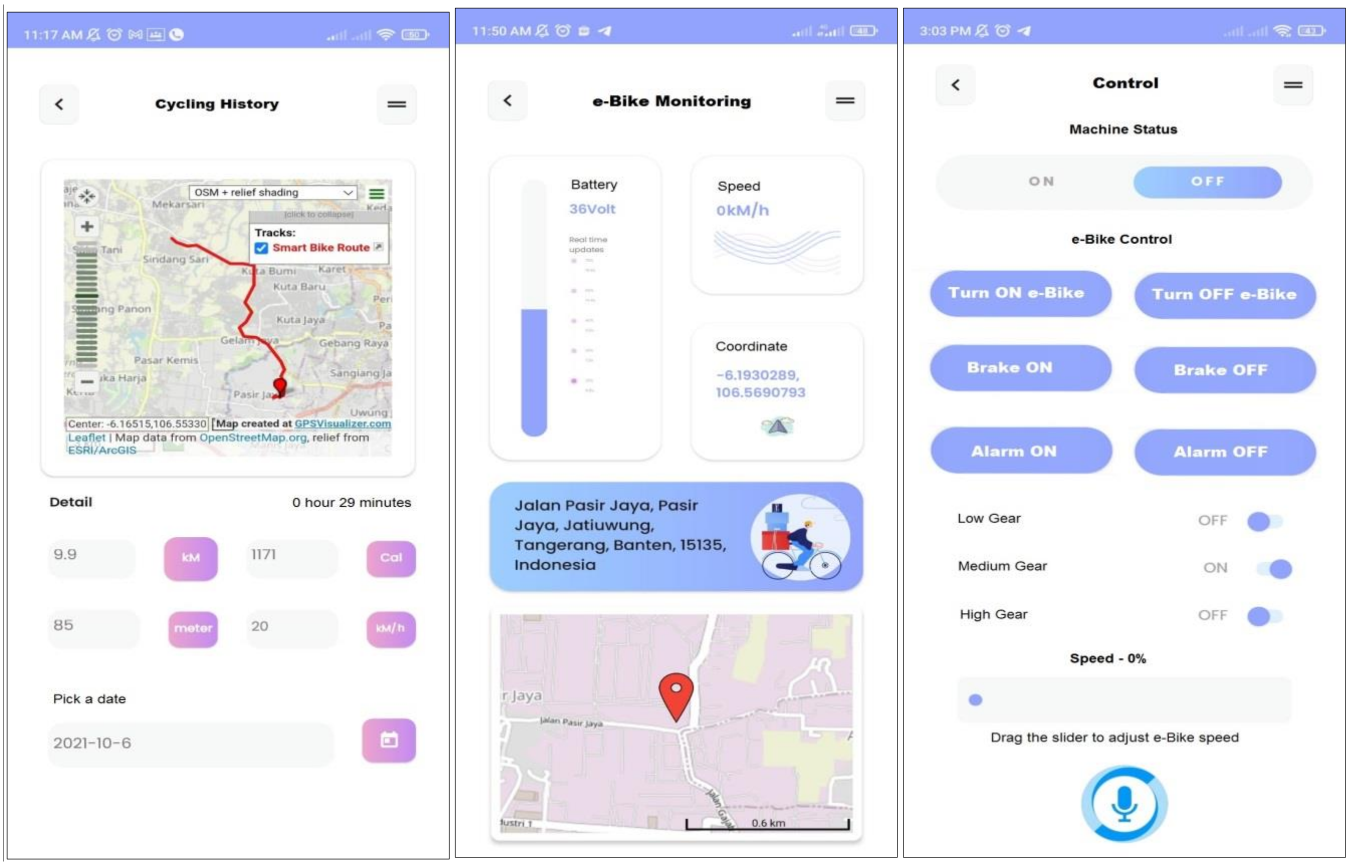
E. Electric Bicycle Control

Another advantage of the “GO-WES Pro” application is its ability to control electric bicycles anywhere as long as there is an internet network. Remote control of electric bicycles has been developed previously [19]. The research utilized Bluetooth communication media to connect Android smartphones with electric bicycles. One of the experienced obstacles was the maximum distance limit, which was 15 m. The system still runs normally when the distance between the smartphone and the electric bicycle is less than 15 m. However, the system becomes an error when the distance exceeds the maximum limit.

In addition, “GO-WES Pro” has another advantage, which is that besides being able to control the electric bike by pressing a button as shown in Fig. 5(c), it is also equipped with a voice command feature, as shown in Fig. 6. The voice command feature can be activated by pressing the microphone button or by bringing the hand to the front camera. The new “GO-WES Pro” application is currently equipped with sixteen voice commands in Indonesian. The speech recognition technique in this application uses the Google Speech to Text service.

When the electric bicycle is turned on, the “GO-WES Pro” application will send a GET command to the webserver to change the relay status. The employed relay system is a normally closed (NC) mode relay, with data 1 (high) for relays in open-circuit conditions and 0 (low) for relays in closed-circuit conditions. Therefore, to turn on the electric bike, the data in the database will be changed from 1 to 0, as well as the other components. The used relay data is shown in Table IV.

Specifically, for controlling the maximum speed limit (in the “GO-WES Pro” application, called the gear setting), it was performed by combining the settings on relay 2 and relay 3, as shown in Table V. The term gear is used in applications because



(a) (b) (c)

Fig. 5 Application interface display, (a) trip history tracking, (b) electric bicycle real-time monitoring, (c) electric bicycle control.

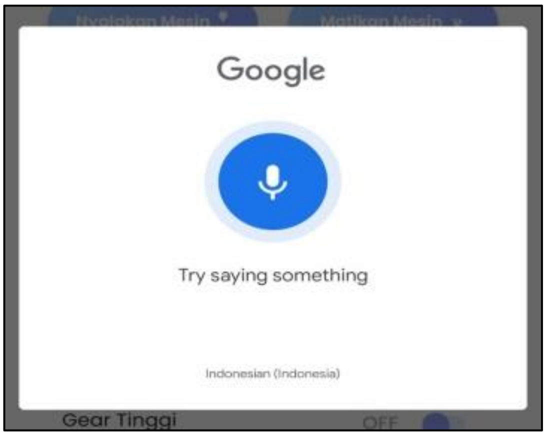


Fig. 6 Display interface when voice control is activated.

people are familiar with gear settings on cars and motorcycles for speed control.

Electric bicycle speed control can be done by moving the speed setting slider or saying “speed up” or “decelerate” after activating the voice command feature. This speed setting is connected to the Data 1 component, as shown in Table IV. Furthermore, the “GO-WES Pro” application will send data in the form of a percent speed converted linearly by the PHP program in the range 0-255, which the microcontroller will later read. The data was converted to a digital value range of 0-255

TABLE IV
INPUT PARAMETERS FROM MICROCONTROLLER TO CONTROLLER

Component	Value	Description
1st Relay	1 (OFF) or 0 (ON)	Turn ON/OFF of electric bike
2nd Relay	1 (OFF) or 0 (ON)	Control of maximum speed
3rd Relay	1 (OFF) or 0 (ON)	Control of minimum speed
4th Relay	1 (OFF) or 0 (ON)	Turn ON/OFF of alarm
1st Data	0 to 255	speed control

because the employed microcontroller used an 8bit conversion. The value would be converted into an analog voltage of 0-5 V to be sent to the electric bicycle controller. The correlation between the percentage of speed, voltage, and speed of the electric bicycle measured in the medium speed limit mode (medium gear) is shown in Table VI.

From Table VI, it can be seen that the change in speed is not linear. The percentage of speed 0-40% or voltage 0-2.0 V has not been able to drive a BLDC motor. The comparison of the percentage change in speed to the change in the speed limit (medium, high, low-speed gear settings) is shown in Fig. 7.

In Fig. 7, it can be seen that the medium and high gear modes have the same lower limit for the percentage of speed, which is 40% or 2 V, while the lower speed limit for low gear mode is 50% or 2.5 V. After passing the lower limit of the stress, the speed has a linear nature. For the speed regulation to be linear, the speed setting was changed by setting the voltage lower limit

TABLE V
COMPARISON OF SPEED LIMIT MODE (GEAR SPEED) TO MAXIMUM SPEED

Setting Type	Maximum Speed	Configuration
Low speed limit (low gear)	15 km/h	2nd relay ON and 3rd relay OFF
Medium speed limit (medium gear)	30 km/h	2nd relay OFF and 3rd relay OFF
Maximum speed limit (maximum gear)	40 km/h	2nd relay 2 OFF and 3rd relay ON

TABLE VI
CONVERSION OF SPEED PERCENTAGE TO DIGITAL VALUE, VOLTAGE, AND BICYCLE SPEED

Speed Percentage	Digital Value	Voltage (V)	Speed (km/h)
0%	0	0	0
10%	26	0.50	0
20%	51	1.00	0
30%	77	1.50	0
40%	102	2.00	0
50%	128	2.50	8
60%	153	3.00	15
70%	179	3.50	21
80%	204	4.00	28
90%	230	4.50	35
100%	255	5.00	40

to 2 V (equivalent to a digital value of 102). The speed setting follows (4).

$$V_{digital} = 102 + \%Kec \times (255 - 102) \quad (4)$$

The digital voltage value ($V_{digital}$) in (4) would be sent to the microcontroller to be converted into an analog voltage to control the speed. Using this method, the speed control is already linear, as shown in Fig. 8. The average value of R^2 (*R*-squared) is 0.9984. In this setting, speed control is already linear.

This application uses a SIM800L device as a communication medium. SIM800L has an internet network connection with GPRS type (2G). It has an impact on the occurrence of a time delay between when the command is given from the Android smartphone to the appearance of a response on the electric bicycle. The measurement delay is still relatively high, with an average of 8.82 s, as shown in Table VII. Future research is expected to reduce this time delay to improve the system.

VII. CONCLUSION

The "GO-WES Pro" application is an Android-based application built using Kodular. This application can control the electric bicycle remotely via the internet. Some of its features included turning on and off the electric bicycle, adjusting the speed gear position, adjusting the speed, turning on the alarm, tracking the last location, tracking location history, and measuring calories using the MET method. The control process can be done by pressing a button or voice command using the Google Speech to Text service. This application has been tested using the black box method with 100% successful results. Calorie measurement using the MET method has an accuracy of 94.24% compared to calorie measurement equipment on the market. Speed control can be done linearly with an R^2 of 0.9984.

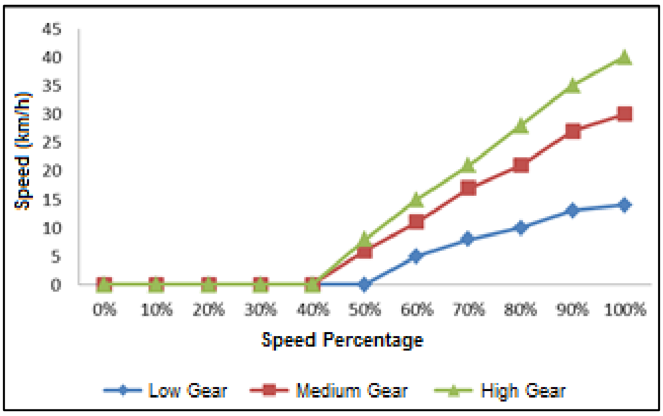


Fig. 7 Comparison of the speed setting to rated speed percentages.

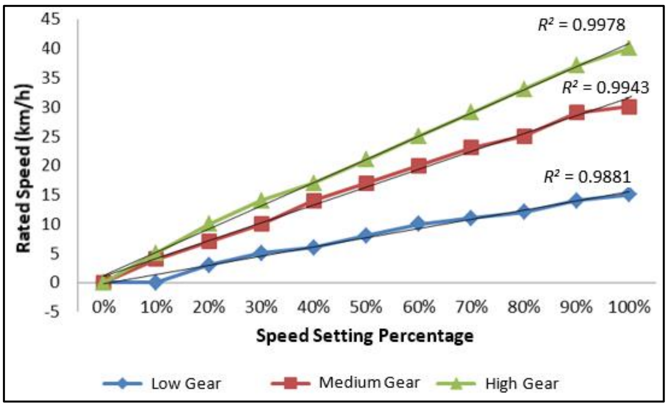


Fig. 8 Comparison of the speed setting to rated speed percentages after modification.

TABLE VII
DELAY RESPONSE TIME

Test	Time Delay (s)
1	10.29
2	10.36
3	8.66
4	8.98
5	5.81
Average	8.82

It is possible to use communication devices with 3G or 4G network access in future research. In this study, the utilized communication device was SIM800L with a 2G network; therefore, there was still a time delay in executing commands. In addition, by modifying the controller, it is possible to develop an electric bicycle into a semi-autonomous one that can adjust the speed automatically, depending on the presence of objects before it. Another thing that can be developed is the integration of health measurement devices (such as heart rate) into the application.

CONFLICTS OF INTEREST

The author declares that there is no conflict of interest in the research process or the writing of this scientific article.

AUTHOR CONTRIBUTIONS

Conceptualization, Muhammad Ridwan Arif Cahyono; methodology, Muhammad Ridwan Arif Cahyono; software, Muhammad Ridwan Arif Cahyono and Surya Wirawan; validation, Muhammad Ridwan Arif Cahyono, Surya Wirawan, and Ita Mariza; formal analysis, Muhammad Ridwan Arif Cahyono; data processing, Muhammad Ridwan Arif Cahyono; writing—original drafting, Muhammad Ridwan Arif Cahyono and Ita Mariza; writing—reviewing and editing, Muhammad Ridwan Arif Cahyono; visualization, Muhammad Ridwan Arif Cahyono and Surya Wirawan.

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REFERENCES

[1] M. Tambrin and F. Rozi, "Pengaruh Merek dan Harga Sepeda Polygon terhadap Keputusan Pembelian (Studi Literatur)," *Eco-Entrepreneur*, Vol. 6 No. 1, pp. 43-48, 2020.

[2] E.T. Ramadhan and B. Tristiyono, "Design Requirements & Objectives Sepeda Listrik untuk Siswi Sekolah Menengah Melalui Riset Konsumen," *J. Sains dan Seni ITS*, Vol. 8 No. 1, pp. 45-50, 2019.

[3] L.D. Rumpa, "Desain dan Implementasi Instrumen Digital Pengukur Kecepatan, Jarak dan Pembakaran Kalori pada Sepeda Gunung Berbasis Mikrokontrol Atmega32," *J. Tek. Dynamic Saint*, Vol. 2, No. 2, pp. 326-337, 2016.

[4] J. Gunawan, M. Rivai, and Tasripan, "Kontrol Kecepatan Motor Sepeda Listrik Menggunakan Force Sensor dan Elektromiografi (EMG)," *J. Tek. ITS*, Vol. 7, No. 2, pp. A343-A348, 2019.

[5] M.A. Rachmadi, M.A. Muslim, and E. Yudaningtyas, "Sistem Kontrol Kecepatan Sepeda Listrik Menggunakan Metode *Self-Tuning* Parameter PI dengan Metode Logika Fuzzy," *J. EECCIS*, Vol. 10, No. 1, pp. 26-32, 2016.

[6] E.A. Siddiq and H. Effendi, "Sistem Monitoring Sepeda Motor Berbasis Mikrokontroler Menggunakan GPS," *JTEV (J. Tek. Elektro, Vokasional)*, Vol. 6, No. 2, pp. 383-390, 2020.

[7] A. Harijanto, Z.A. Adi, and B. Supriadi, "Sistem Monitoring Arus dan Tegangan pada Baterai Kendaraan Bermotor (ACCU) Berbasis Arduino Uno," *FKIP E-Proceeding*, Vol. 2, No. 1, pp. 1-7, 2017.

[8] H. Sujadi, T.F. Prasetyo, and P. Paisal, "Pengembangan Sistem Monitoring Keamanan Sepeda Motor Berbasis Internet of Things," *J-Ensitec*, Vol. 5, No. 1, pp. 226-231, 2018.

[9] D.T. Arsari, "Legalitas Penggunaan Sepeda Listrik sebagai Alat Transportasi Menurut Perspektif Hukum Pengangkutan di Indonesia," *Jurist-Diction*, Vol. 3, No. 3, pp. 903-920, 2020.

[10] C.N. Alam, K. Manaf, A.R. Atmadja, and D.K. Aurum, "Implementation of Haversine Formula for Counting Event Visitor in the Radius Based on Android Application," *2016 4th Int. Conf. Cyber, IT Service Manag.*, 2016, pp. 1-6.

[11] Yulianto, Ramadiani, and A.H. Kridalaksana, "Penerapan Formula Haversine pada Sistem Informasi Geografis Pencarian Jarak Terdekat Lokasi Lapangan Futsal," *Inform. Mulawarman: J. Ilm. Ilmu Komput.*, Vol. 13, No. 1, pp. 14-21, 2018.

[12] Y. Miftahuddin, S. Umaroh, and F.R. Karim, "Perbandingan Metode Perhitungan Jarak Euclidean, Haversine, dan Manhattan dalam Penentuan Posisi Karyawan," *J. Tekno Insentif*, Vol. 14, No. 2, pp. 69-77, 2020.

[13] I.W.T. Andhika and Umar, "Monitoring Kalori yang Terbakar pada Penggunaan Sepeda Statis Berbasis Arduino," Undergraduate Thesis, Universitas Muhammadiyah Surakarta, Surakarta, Indonesia, 2021.

[14] V. Febrian, M.R. Ramadhan, M. Faisal, and A. Saifudin, "Pengujian pada Aplikasi Penggajian Pegawai dengan Menggunakan Metode Blackbox," *J. Inform. Univ. Pamulang*, Vol. 5, No. 1, hal 61-66, 2020.

[15] I. Mulasastra and W. Kao-ian, "Android Application for Connecting Cycling Routes on Strava Segments," *J. Inf. Commun. Converg. Eng.*, Vol. 17, No. 2, pp. 142-148, 2019.

[16] M.S. Budiana, A. Mulyana, and A. Hartaman, "Desain dan Implementasi Aplikasi Android untuk Penentuan Rute dan Pelacakan Posisi Kendaraan Menggunakan Perangkat GPS secara Interaktif," *eProc. Appl. Sci.*, Vol. 3, No. 3, pp. 2084-2091, Dec. 2017.

[17] V. Bernando, "Pengembangan Sistem Pelacakan Kendaraan Menggunakan Modul GSM dan GPS Berbasis Mikrokontroler ATmega328," *J. Sist. Teknol. Inf. (JUSTIN)*, Vol. 4, No. 3, pp. 455-460, 2016.

[18] D. Dahlan, D.L. Zariatin, and N. Wibowo, "Perancangan Sistem Pemantauan Kecepatan dan Pengelolaan Baterai pada Sepeda Motor Listrik 3 kW," *Pros. Sem. Rekayasa Teknol. (SemResTek)*, 2018, pp. 366-372.

[19] R. Asnawi, A.C. Nugraha, A. Asmara, and I.G. Dangin, "Integrating Android Smartphone and Microcontroller System for Controlling and Monitoring the Two Wheels Electric-Bike," *Proc. 1st Int. Conf. Technol., Vocat. Teach. (ICTVT 2017)*, 2017, pp. 89-93.