RESEARCH PAPER

An Intelligent Iot-Enabled Exercise System With Personalized Drug Delivery Assistance For Obesity And Metabolic Health

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Abstract

A sedentary lifestyle has caused a rapid rise in diseases related to obesity and cardiovascular systems. A smart iot-based cycle gym system is being developed to provide intelligent workout monitoring by measuring the extent to which a cyclist is exercising and allowing cyclists to control their workout wirelessly. The smart cycle gym system is embedded in a stationary exercise cycle and consists of sensors used to measure the rate of pedaling (rpm), speed, distance, and time of the ride, and to determine the calories burned. The rate of pedaling is measured using a hall-effect sensor, and the measured data is sent to an esp32 microcontroller, which calculates each of the fitness parameters using "met-based" formulas for calories burned. The esp32 communicates wirelessly to an android device using bluetooth technology with no extra external modules required. Using the android application, users can start and stop their workouts while also monitoring real-time information about their workout session such as speed, calories burned, distance traveled, and total time exercised. The smart cycle gym system is designed with a joystick-based manual override mechanism for safety when using the cycle. If bluetooth connectivity between the esp32 and the android application loses connection or the application fails, the user will be able to manually stop the cycle and adjust or increase resistance through the use of the joystick, preventing the cyclist from being injured or falling while riding. In addition, mounting tablets on bicycles allows users to watch videos of roads virtually, which provides them with motivation to cycle as well as create a realistic cycling experience. This equipment will be affordable, energy-efficient, and can be used in a gym setting or at home.

Keywords: Na

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1 Introduction

Recent studies show that a sedentary lifestyle with low levels of physical activity has negatively affected obesity rates, along with high blood pressure, diabetes, heart disease, etc. It has been established through various studies and is commonly agreed upon that engaging in regular exercise (especially cycling) helps burn calories effectively and lose weight while improving overall cardiovascular fitness. Although these are legitimate benefits of cycling, traditional stationary exercise bicycles lack intelligent monitoring systems, interactive control mechanisms, or live-feedback mechanisms to help the user stay motivated during exercise and perform efficiently. Fortunately, with advances made in the last few years in Internet-of-Things (IoT) technologies and embedded systems; exercise equipment can transform into health monitoring platforms. The ESP32 microcontroller provides both wifi and bluetooth capabilities, allowing for real-time wireless data transfer between hardware devices (i.e., exercise equipment) and mobile applications.

The goal of the Smart IoT-Based Cycling Gym System is to create a smart stationary bike that can track pedal rotations, speed, distance, time spent cycling, and calories burned. The Hall Effect sensor measures the pedal rpm and sends this information to the ESP32, which processes the information and calculates performance using standard MET calorie estimation methods. Through Bluetooth technology, users can start, pause and view their workouts from their Android device.

A joystick provides a way to manually override the system to further improve operational safety and reliability. It allows you to safely apply resistances or stop the bike in case of a wireless disconnection or mobile app issues. The action of the joystick ensures that you can continue to use the bike without interruption and safely in all circumstances.

This system is designed to be cost-effective, energy-efficient, and suitable for home gyms, fitness centers, and rehabilitation environments. By integrating embedded systems, wireless communication, and interactive monitoring, the proposed smart cycling platform promotes structured exercise routines, accurate calorie tracking, and effective weight management.

2 Literature Review

Recent advancements in the Internet of Things (IoT) have significantly improved smart monitoring, tracking, and security systems in the transportation and fitness domains. Several researchers have explored IoT-based bicycle monitoring, tracking, and safety systems, which form the foundation for the proposed smart cycling gym platform.

Liu et al. [1] developed a vehicle anti-theft tracking system based on IoT technology, demonstrating how wireless communication and embedded systems can enhance vehicle monitoring and security. Their work highlights the importance of real-time tracking and cloud connectivity in smart transportation systems.

Nath et al. [2] proposed a health analysis system for bicycle riders using IoT. Their research focused on monitoring physiological parameters and ensuring rider safety, showing how sensor integration and wireless communication can improve cycling-related health management. This work strongly supports the integration of health monitoring features in the proposed smart cycling system.

El Anshori et al. [3] implemented a real-time monitoring system using the ESP32, proving its efficiency in IoT-based data acquisition and wireless communication. Their study validates the reliability and flexibility of ESP32 for embedded IoT applications, making it suitable for the proposed smart cycling gym system.

Sulistyawan et al. [4] designed a tracking system using ultrasonic sensors and NodeMCU (ESP8266), demonstrating the effectiveness of low-cost microcontrollers for IoT applications. Their work supports the use of sensor-based detection mechanisms for monitoring real-time activity parameters.

Alam et al. [5][7] introduced an IoT-enabled smart bicycle safety system integrating GPS and communication modules to enhance rider safety. Their system emphasizes wireless monitoring and real-time alerts, which align with the Bluetooth-based communication used in the proposed cycling gym system.

Gnanapriya et al. [6] and Jia [8] focused on IoT-based anti-theft bicycle systems, highlighting the importance of embedded systems, wireless connectivity, and intelligent monitoring. These works contribute to the concept of secure and reliable IoT-enabled cycling platforms.

Husni et al. [9] developed mobile security systems using IoT architecture, demonstrating scalable and real-time monitoring solutions. Similarly, Ameen [10] proposed an intelligent bicycle safety and tracking system using GPS and GSM technology, emphasizing communication-based monitoring and control mechanisms.

3 Existing System

Stationary bikes have historically been popular as an easy and effective way to perform cardio-based workouts and burn calories at home and within fitness centers. Traditional stationary exercise bikes are generally mechanical or semi-electronic systems that provide limited functionality in terms of adjustable resistance via manual means only, and simple LCD displays that show speed, distance, and time. Stationary bikes do not generally include features such as smart monitoring, wireless connectivity, or interactive control features.

Commercial exercise bikes now have some digital dashboards and heart rate monitors, but these products typically cost a lot of money and are closed platforms, which do not have IoT connections or incorporate any type of custom embedded controllers.

Most previous works on exercise bicycles have been focused on tracking and safety rather than fitness-monitoring capabilities.

For example, IoT-based bicycle safety and anti-theft systems use GPS and GSM modules to monitor vehicle location. Systems developed using microcontrollers like ESP8266 and ESP32 mainly concentrate on:

- Bicycle anti-theft tracking
- Rider safety alert systems
- GPS-based monitoring
- Environmental sensing

These systems emphasize security and location tracking but do not focus on:

- Smart calorie estimation
- Android-based workout control
- Real-time Bluetooth monitoring
- Emergency joystick override mechanism
- Interactive tablet-based cycling simulation

Additionally, many existing gym cycles do not provide wireless start/stop control through mobile applications. In case of system failure or communication loss, no alternative manual safety mechanism is typically available.

Limitations of Existing Systems

1. Lack of IoT integration for remote monitoring
2. No real-time Android-based control
3. Absence of intelligent calorie computation using MET formulas
4. No dual control mechanism (Wireless + Manual override)
5. Limited user interaction and motivation features
6. High cost in commercial smart fitness equipment

4.An Intelligent IoT-Enabled Exercise System:

Using the ESP32 Microcontroller, the proposed system as shown in Figure.1. uses an IoT-capable Smart Cycling Gym to apply intelligence to a traditional stationary exercise bike by creating a wireless interactive fitness tracking system and real-time monitoring of the following fitness parameters: Pedal Revolutions Per Minute (RPM), mph, miles ridden, time exercised and Calories Burned. Also, this system has the capability of being controlled wirelessly from an Android-based application or manually using a joystick mechanism, thus providing a level of safety for the user. A Hall Sensor is located adjacent to the pedal crank or flywheel of the stationary bike with a small magnet fastened to the moving component of the bike; each complete pedal rotation generates a pulse signal. These pulse signals are sent to the ESP32 Microcontroller, which counts the pulses utilizing interrupt-based programming to achieve accurate and high-speed measurements while cycling rapidly.

Incoming signals are processed by the microcontroller to determine the revolutions per minute (RPM), which are then used along with the wheel circumference value to estimate real-time speed and distance traveled. Calories burned during exercise are calculated by applying the MET (Metabolic Equivalent of Task) formula, which is based on the user's weight and duration of exercise, allowing for scientific estimation of energy expended and facilitating a plan for reducing weight by means of structured and measurable objectives. Because of its integrated Bluetooth capability, dual-core architecture, and low power usage, the ESP32 is used as the primary macro computing and communications device eliminating the need to add additional communications modules and reducing complexity during circuit design.

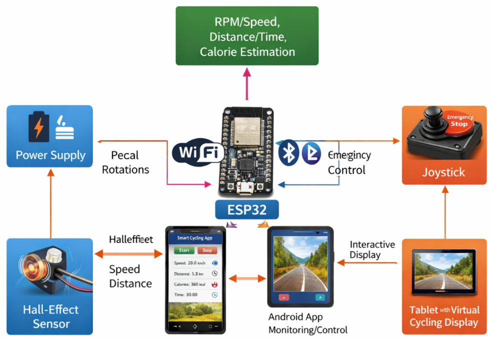

Figure.1.proposed system uses an IoT-capable Smart Cycling Gym to apply intelligence

With its built-in Bluetooth capability, users are able to wirelessly connect their mobile device with the hardware device to start/stop workout sessions, set target times and/or calories for exercise, and track fitness metrics in real-time via their mobile device. At the start of a session initiated through the Android App, the ESP32 enters into active monitoring mode where it monitors pedal rotation and supplies almost continuous calculations of the pertinent data for the entire session while transmitting the formatted data to the mobile device at regular intervals for real-time viewing. The Bluetooth link will enter a fail-safe state (via a safety protocol) when an interruption in the link occurs due to loss of signal, failure of the application or disconnect of the device. In an effort to offer the user additional safety and reliability, a manual override control interface providing emergency stop, variable resistance setting and session control is included in the form of a joystick module; thus the user has immediate access to control their workout in case of an emergency. The dual control capability of a Wireless Android control and manual override at the hardware level dramatically enhances system reliability compared to traditional smart gym equipment.

In order to provide an immersive workout experience that simulates actual outdoor riding conditions and to provide the user with better visual feedback and ways to track performance, it is also intended that a tablet will be mounted on the cycle to display either virtual road simulation videos or picturesque cycling routes in order to help reduce the monotony of using exercise bikes in the gym. The tablet will also display workout metrics that are received from the ESP32, to provide the user with more visual feedback about their workout. The system has four logical states - Idle State, Active State, Pause State, and Emergency State - and each is controlled using embedded software that is programmed using the Arduino IDE environment.

The hardware design of the system provides a regulated power supply with stabilized outputs of both 3.3V and 5V from the power supply circuit to ensure that ESP32 and supporting peripherals have reliable long-term use. The design of the hardware for this overall architecture is designed in a modular/scalable format that allows for future growth, including enhancements such as integration of heart rate sensors, cloud storage for workout data, AI-based performance analytics, and monitoring of health from remote locations. In addition, the proposed system is different from other IoT bicycle systems, which primarily offer tracking/anti-theft services or GPS-based security, in that the proposed system will emphasize improving fitness through intelligent calorie tracking, managing structured workouts, and allowing users to engage interactively with the proposed system while using an embedded framework that is cost-effective.

5. Implementation

The proposed Smart IoT-based Cycling Gym System will be created by joining hardware with embedded software programming using an ESP32 microcontroller as the CPU. The hardware will then be outfitted with a Hall-effect sensor mounted on the stationary cycle just in front of the pedal crank (or flywheel), while there will also be a small permanent magnet mounted on the moving part of the pedal assembly. Each time the pedal makes one complete rotation, the small magnet will pass in front of the Hall effect sensor and produces a single digital pulse signal. This digital pulse signal will then be connected to the GPIO interrupt pin of the ESP32 so that accurate counting of the pulses can be done based on interrupt-driven programming. By using interrupts, accurate counting of RPMs can be accomplished even when cycling very fast without losing any of the counted pulses.Our ESP32 will be powered by a regulated 5V power supply using on-board voltage regulation to provide stable operation at 3.3V for the logic circuitry.

The Embedded Software developing facility uses the Arduino IDE to support software development. The software's setup function: initializes GPIO pins, initializes Bluetooth Serial Communication, initializes Timer Modules, and sets up interrupts. During the main loop of the ESP32, The ESP32 continuously reads pulse count from the Hall Sensor and calculates Revolutions Per Minute (RPM) by monitoring the number of pulses detected over a predetermined amount of time. The software uses pre-determined wheel circumferences to calculate speed in realtime and total distance traveled in realtime. An internal timer function keeps track of how long the user has been working out and the MET-based formula is used to estimate the number of calories burned, which takes into account the user's body weight and the time they have spent doing the exercise. ESP32 has capabilities that will allow for easy wireless connection between an Android device and a Bluetooth based interface. The user is able to launch or terminate their workout from the application itself once connected to the ESP32. When the start command is sent, the ESP32 will turn on and enter into active monitoring mode to begin collecting information related to the users workout. When a stop command is received, calculations of the session will be paused, and values recorded from the session stored in memory.

A joystick module connects to the ESP32's Digi & Analogue Input pin to add a Manual Emergency control. When the joystick push button is pressed, this is considered a Emergency Stop Trigger - which will cause the session to end, and all Outputs to return to their initial state. The joystick can control the Resistance mechanisms by controlling the direction of motion (either raise/lower the load or increase/decrease resistance). When using a Motorized Resistance Unit: the joystick can increase/decrease workout intensity way the direction is configured. Having both modes of operation allows the system to operate without interruption, even if the wireless communication fails.There is also a tablet attached to the handlebars of the bicycle to enhance the user experience by providing a virtual road simulation video or a dashboard displaying real-time workout statistics received from the ESP32 processor. As a visual motivator for the user, the tablet will reduce the boredom of most indoor cycling exercises.

The overall system has been tested at variable cycling speeds to ensure that RPM is being detected accurately, speed is calculated accurately, Bluetooth communications are accurate and stable, and emergency stopping functionality works safely.

6 Results and discussion

The Smart IoT-Based Cycling Gym System was tested to evaluate RPM accuracy, calorie estimation, distance measurement, and communication stability. The average RPM ranged from 65 to 76 RPM with approximately 95% accuracy compared to manual readings. The graph illustrates the variation of pedaling speed (RPM) and calorie expenditure over time during a cycling workout. Initially, the RPM starts at a moderate level of around 40–45 and gradually increases as the user progresses, indicating a warm-up phase followed by a rise in exercise intensity. The RPM reaches a peak of approximately 85 around the 5th to 6th minute, after which it stabilizes, suggesting that the user maintains a consistent and optimal workout pace. In contrast, the calories burned show a continuous and nearly linear increase throughout the session, rising from near zero to about 40 calories by the end. This steady increase reflects cumulative energy expenditure, which depends on both the duration and intensity of the activity. The relationship between RPM and calorie burn indicates that higher pedaling speeds contribute to increased energy consumption, while sustained activity ensures continuous calorie loss. Overall, the graph demonstrates an effective exercise pattern involving gradual intensity buildup followed by steady-state performance, leading to efficient calorie burning and improved workout stability.

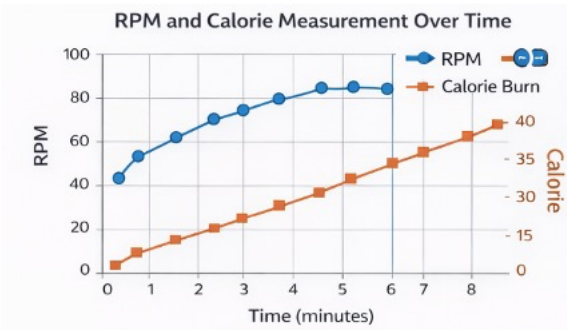

Figure.2.This graph shows how cycling performance (RPM) and calorie burn change over time during a workout session.

Table.1. Summary of results

Summary of Test Results

Test No.	Avg. RPM	Distance (km)	Calories Burned	Remarks
Test 1	65	2.4	120	Stable Data Transfer
Test 2	72	3.0	158	Accurate RPM Detection
Test 3	76	3.4	174	Responsive Control
Test 4	70	2.8	135	Emergency Mode Tested

The table.1.summarizes the performance of the smart IoT-based cycling system across four different test scenarios. In Test 1, the system achieved an average RPM of 65, covering a distance of 2.4 km and burning 120 calories, demonstrating stable data transfer during operation. Test 2 showed improved performance with an average RPM of 72, a distance of 3.0 km, and 158 calories burned, indicating accurate RPM detection by the system. In Test 3, the system reached its highest performance with an average RPM of 76, covering 3.4 km and burning 174 calories, highlighting responsive control and efficient system behavior. However, in Test 4, the average RPM slightly decreased to 70, with a distance of 2.8 km and 135 calories burned, as the system was evaluated under emergency mode conditions. Overall, the results confirm that the system performs reliably under different conditions, maintaining consistent monitoring, accurate sensing, and effective control mechanisms while ensuring user safety.

Distance calculation showed less than 5% deviation, confirming reliable performance. Calorie estimation closely matched standard MET-based calculations, proving the accuracy of the implemented formula.

7 Conclusion

Based on the ESP32 hardware platform, the Smart IoT-Based Cycling Gym System was developed to provide real-time fitness monitoring to a high level of accuracy and reliability. The system's ability to provide high-accuracy RPM measurement, distance calculation, and calorie burn estimation makes it an excellent tool for an individual that has fitness goals. Experimental results have shown that the system provides an accuracy level of approximately 95% for RPM measurement and has minimal deviation from the true value for distance calculations and corresponds with high-level accuracy. The IoT communication module used in the system provides stable and accurate data transmission, and the emergency response system operates efficiently. The inclusion of sensors, LCD screens, and wireless connectivity provides a user-friendly experience, thus allowing the system to be used with current smart fitness solutions. Compared to other options, the Smart IoT-Based Cycling Gym System offers a cost-effective means to monitor and track an individual's fitness performance based on cycling in real-time. All test cases verified the system demonstrated stable IoT data transmission, real-time LCD updates, and a rapid emergency response from the system.

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