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Optimizing the Body Posture of Cyclists to Attain Maximum Cycle Speed Using Embedded Electronics

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***Abstract*— Improving speed performance is an ongoing objective in many domains, such as sports, athletics, and daily life. This study examines how an individual's speed capacity is determined in large part by their posture. This study compares and contrasts multiple postures in an attempt to identify the one with the most potential for speed. Improving speed performance is an ongoing objective in many domains, such as sports, athletics, and daily life. This study compares and contrasts multiple postures in an attempt to identify the one with the most potential for speed. Our findings demonstrate that an individual's choice of posture has a significant impact on their ability to move quickly. The effectiveness of a particular position for gaining velocity is heavily impacted by balance, muscular activation, and aerodynamics. We discovered that the most notable gains in velocity usually come from a well-composed mix of postural adjustments, including a small forward lean to reduce air resistance while maintaining a strong core and leg drive. It's crucial to consider the effects of the terrain and the specific sport or activity when determining the ideal position to enhance speed.**

Keywords*— Cycle, Aerodynamic, Air Pressure, Bernoulli Principle

I. INTRODUCTION

Our goal is to create an innovative embedded hardware system that significantly boosts cyclists' performance by utilizing real-time aerodynamic data. This innovation is based on a well-designed system with state-of-the-art sensors that continuously monitor three critical parameters: the cyclist's angle, air pressure, and speed. Right now, these data streams are intelligently evaluated to give the rider instantly actionable feedback. Whether a cyclist is competing in difficult terrain or riding on a wide road, our technology serves as their own performance coach. For instance, a slight inclination of the handlebars or a tiny adjustment to body positioning are necessary to maximize aerodynamics. The real-time feedback loop helps riders make timely, informed decisions, which improves riding posture and reduces drag. An complete cycling community benefits from this integrated hardware solution in addition to individual riders. Whether you're an amateur aiming to beat your personal best or a professional competing for the podium, this technology levels the playing field. Reduced carbon emissions from other forms of transportation benefit the environment, thus we encourage more people to take up cycling and get better at it. To sum up, our embedded hardware solution for cycling represents a paradigm shift.

The major goal is to examine how different riding postures affect a cyclist's ability to ride at a faster speed. This calls for a thorough examination of the effects that different postures have on things like balance, muscular activation, and aerodynamics. Finding the posture with the greatest potential for speed gain is the study's primary objective. This will be achieved by carefully comparing and analyzing multiple postures to identify the one that optimizes speed performance. Furthermore, the study aims to provide insight on the intricate relationships that exist between posture and critical elements like balance, aerodynamics, and muscular activation, as well as how these relationships affect a cyclist's ability to travel quickly.

II. MOTIVATION AND NOVELTIES

A. *Motivation*

Our main goal is to elevate the standard for cycling performance, and we pursue this goal with a ferocious dedication to innovation and perfection. In the ever-improving sport of cycling, we can make good use of real-time aerodynamic data. We usher in a new era of cycling with our incorporation of sensors that track speed, air pressure, and rider angle. It aims to revolutionize riding itself while also enhancing performance. We are not only making a tool, we are making a difference for the future of cycling. "Whole-Body Pose Estimation in Human Bicycle Riding Using a Small Set of Wearable Sensors" was another intriguing research.

B. Novelty

In order to optimize body posture and improve speed performance, real-time aerodynamic data is utilized in the research article to present a novel embedded hardware solution that promises to revolutionize cycling performance. This research is unusual because it takes a cutting-edge approach to enhancing cycling efficiency using novel approaches and state-of-the-art technologies.

The focus on improving aerodynamics with small changes to the cyclist's body position, handlebar tilt, or stance is one of the main innovations of this research. By enabling cyclists to make well-informed decisions quickly, the real-time feedback loop improves cycling posture and lowers drag. This technology has far-reaching consequences for the entire cycling community, in addition to helping individual riders. It creates parity between enthusiasts and amateurs by granting access to professional-level performance.

The thorough analysis of pertinent research publications that determined the project's course is disclosed in the electronics section. A new feature of this study is the integration of the MPU6050 sensors, which track rider attitudes. These sensors help to comprehend the intricate relationships between posture, aerodynamics, muscular activation, and balance in addition to being utilized to measure angles. This research is unique in that it takes a multifaceted approach to analyzing cycling posture for performance optimization. The thorough attention to detail in resolving the technological issues given by the study is demonstrated by the implementation of two MPU6050 sensors on a single Arduino Nano using the I2C communication protocol.

III. LITERATURE REVIEW

The study was conducted by Forte et al. [1] ,this study used analytical methods and numerical simulations to compare a cyclist's performance in three different riding postures. A professional road cyclist competing at the top level in the country was recruited for this study. A 7-kg bicycle was being pushed by a 55-kg rider. The subject was scanned while riding a competitive bicycle, wearing race gear and a helmet, in three different positions: upright, dropping position with the handlebars down, and elbows position with the subject leaning on them. The coefficient of drag was calculated using numerical computer fluid dynamics simulations with the Fluent CFD tool, and the result was 11.11 m/s. After then, cycling performance was assessed between 1 and 22 m/s using a number of assumptions. The drag coefficients at different speeds and places ranged from 0.16 to 99.51 N. The cyclist's mechanical power fluctuated between 0% and 23% when compared to the upright position and between 0% and 21% when compared to the lowered position. The elbows position required 2 to 14% less energy than the lowered position, but the upright posture required 2 to 16% more energy from the cyclist. Riding aerodynamics, as studied by Malizia et al. [2], has been increasingly popular in recent years due to the development of more aerodynamic bicycles, wearing gear such as helmets and skinsuits, as well as the invention and application of creative riding postures. We now have a better understanding of the flow topology around a cyclist as well as the aerodynamic interactions between bicycles, other cyclists, and nearby cars. However, there was some understanding of the impact of aerodynamics on cycling performance in the late 1800s and early 1900s, as evidenced by the creation of aerodynamic fairings and recumbent bicycles, the adoption of dropped cyclist positions, and the holding of drafting races. This understanding was primarily empirical. Through an illustration of the evolution of aerodynamic knowledge in cycling from the earliest days to the most recent state-of-the-art, this work aims to successfully direct future research. Consequently, this paper provides a comprehensive overview of the historical and contemporary state of cyclist aerodynamics, focusing on three main areas: (i) cycling flow topology and the wind's influence; (ii) the aerodynamics of an individual cyclist and his or her wearable components; and (iii) the aerodynamic interaction between a cyclist and other cyclists or nearby vehicles. Finally, some potential directions regarding aerodynamics for cyclists are discussed. Through an illustration of the evolution of aerodynamic knowledge in cycling from the earliest days to the most recent state-of-the-art, this work aims to successfully direct future research.In the research project that Ali Kassim and colleagues [3]There is a growing movement to develop and promote sustainable modes of transportation on a global scale. Bicycling is an important mode of transportation that offers practical solutions to the ongoing problems with pollution and traffic congestion. The accuracy of the rider's location is considered to be a critical component in bicycle speed calculations. Cyclist speed data is required for the precise design of traffic control measures, safety analyses, and sight distance evaluations. Numerous speed-measuring techniques and results can be found in the literature. In this study, the peer-reviewed publications that outline several techniques for measuring cycling speed are thoroughly examined. This review highlights the flaws in the research and talks about the accuracy of the measuring procedures. The following areas comprise these limitations: limited range of movement directions, selection of cyclists observed, seasonal variation in measurements, thoroughness of findings reporting, equipment limitation reporting, and measurement validation. The report provides a summary of previous research on bike speed statistics. This study also looks at the level of automation in speed measurement. A manual approach is any cycling speed estimation technique that needs human input during field data collection or analysis. Other categories were made for automated and semi-automated measuring processes. To determine whether the reported cycling speed differed depending on whether the cyclists were riding on the road or in an intersection, a meta-analysis was conducted. The results of the unpaired test showed that there is no statistically significant difference between the average bike speeds at road sections and signalized junctions at the 95% confidence level. The study emphasizes how automated computer vision methods are becoming more and more crucial for speed monitoring. In the essay, the advantages of computer vision techniques are contrasted with those of alternative measuring approaches. The research done by Yan Xingchen and colleagues [4] As a result of issues with air pollution, traffic in cities, and public health, cycling is becoming a more popular mode of mobility. Cycling attributes have also changed noticeably as a result of the introduction of electric bicycles and bike-sharing schemes, especially speed. The study sought the optimal distribution of bicycle riding speed, taking cyclist characteristics, vehicle type, and track qualities into consideration in order to give a stronger basis for theoretical derivations and simulations of bicycle-related traffic. K-means clustering on the speed subcategories was done, and the optimal number of clusters was found using this method. After fitting 15 well-known models to the grouped speed data, the best-fit distribution was determined using the Bayesian information criterion, Akaike information criteria, and Kolmogorov-Smirnov test. The following were the outcomes attained: (3) By integrating stability and overall performance, the generalized extreme value was shown to be the best-fit distribution of cycling speed. Out of the common distribution, gamma, lognormal, and generalized extreme value were the top three models to fit the three clusters of speed dataset. Combinations of bicycle type, bicycle lateral position, gender, age, and lane width produced three clusters of bicycle speed sub-clusters. It was conducted by Ruiyan Li et al. (5)Traffic congestion and environmental pollution are major challenges that have grown worse due to urban expansion; nevertheless, choosing to commute by bicycle can considerably lessen these problems. Using a data sample from a bicycle survey in Xi'an, this study first employs a stated preference (SP) survey to evaluate the factors that, in the cyclists' opinion, impact their path selections. It is found that the main factor determining the percentage of bicycle trips is mixed traffic. The locations of cycling amenities are registered when they are passed by, and the OD and route of riders are subsequently collected through a revealed preference (RP) survey. Based on the aforementioned findings, a multivariate linear regression model is created for the logarithmic value of the actual riding distance and the cycling distance of different bicycle facilities. It has been found that when 1 km of cycling lanes are introduced, separated by barriers, dashes, adjacent bus lanes, and cycling lanes without bicycle amenities, cyclists are willing to increase the cycling distance by 1.968 km, 1.433 km, and 1.405 km. In the investigation carried out by Turpin et al. [6]Accurate measurements of kinematic, kinetic, motor, and physiological aspects are made possible by the wide range of tools available in modern biomechanical research facilities.The forces applied at the pedal, saddle, and handlebar as well as the joint torques produced by muscular activity are measured using force sensors, motion capture equipment, and electromyographic recording. These techniques enable precise biomechanical analysis of cycling motions. Even so, cycling performance is still difficult to fully understand, even with such indicators having decent accuracy. Both experts and novices are requesting an increasing variety of biomechanical testing services. Understanding the relationship between biomechanics and performance can occasionally be challenging due to limits imposed by the human physiology, musculoskeletal system, and bicycle. Along with emphasising the need of measuring output metrics like power production, recent studies have also highlighted the importance of evaluating intrinsic components like the cyclist's coordination. In this narrative review, we offer a variety of techniques for assessing a cyclist's biomechanics together with interpretive elements, and we show that determining whether a technique is optimal or not can be difficult. The trial carried out by Hsiao, S. et al. (7) The creation of bicycles with unique designs has gained popularity recently. Therefore, comfort of riding should be taken into account when constructing a bicycle. The ergonomic notion of "fitting object to human body" was taken into consideration when building the bicycle frame used in this study. Initially, the primary riding posture feature points were automatically determined by the image processing technique. During the measuring process, the optimal riding posture was identified experimentally, which allowed for the determination of the locations of the human body's feature points and joint angles. Then, using the measurement data, the handlebar, saddle, and crank center were determined and applied to the frame design of multiple bicycle models. Lastly, this study included a handy frame size chart for commonly used bicycle types, which should be of interest to bicycle designers.

IV. THE PROBLEM

Aerodynamics has a big influence on cycling performance. Bike riders at high speeds have to deal with air resistance or drag force. The cyclist uses 90% of his energy to overcome drag forces caused by air pressure. Their speed and efficacy are so restricted. A bicycle cannot function better or reach higher speeds than air resistance. Currently, cyclists are not able to receive real-time feedback on how they should position themselves in respect to air resistance, thus they are unable to know exactly what modifications they need to make in order to perform at their best. Other scientific methods, like as employing wind tunnels to measure aerodynamic performance, are usually labor-intensive and out of the reach of the majority of riders. They are unable to offer real-time input during realistic cycling situations and do not simulate the outdoor conditions that the majority of riders experience.

The objective is to develop an embedded hardware system that provides cyclists with quick positioning by utilizing real-time aerodynamic data. It will be fitted with sensors to measure and analyze data related to the cyclist's speed, angle, and air pressure. The rider may receive real-time input from it. The rider can then make educated decisions to lessen drag and enhance posture. Overall cycling performance will increase as a result.

V. METHODOLOGY

A. Theory

A method for measuring the air pressure was determined using the Bernoulli equation.

Energy per unit volume before = Energy per unit volume after

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$$

Where:

ρ –is the density of the fluid at all points in the fluid.
g– is the acceleration due to gravity,
v– is the fluid flow speed at a point,

z-is the elevation of the point above a reference plane, with the positive z-direction pointing upward—so in the direction opposite to the gravitational acceleration, and

$P_1$and P_2 -is the pressures at the chosen point

With the use of a differential pressure sensor, P2-P1 may be computed. P1 is the atmospheric pressure. Since this model will be tested on a flat track, the height will never be more than zero. V1 will also be 0 because the cycle is initially stationary. In order to calculate V2, the air density will be set to a uniform value. You may calculate the cyclist's exposure to air resistance using the airspeed, or V2. It was chosen to measure the angles of the rider using the MPU6050.

B. Electronics

1) Prototype

The detailed investigation of research publications concentrating on the use of embedded hardware for bicycle posture analysis was the first step in the literature review. In one notable work, "Wireless Cycling Posture Monitoring Based on Smartphones and Bluetooth Low Energy," IMU sensors were used to create a real-time cyclist posture monitoring system. The project's scope differed from the study's by monitoring head, back, and arm angles rather than knee angles, although appropriate sensor sites on the user's body were still determined. In another pertinent work, "Whole-Body Pose Estimation in Human Bicycle Riding Using a Small Set of Wearable Sensors," the whole-body stance of the cyclist was calculated using four gyroscopes and two IMU sensors. Due to the use of identical sensor types, it was required to address each MPU6050 sensor's individual identities in order to interface them with a single Arduino Nano utilizing the I2C communication protocol. Two MPU6050 sensors were first connected to an Arduino Nano, with the second sensor being given a separate address by setting the AD0 pin to 5V rather than VCC. This configuration worked well since the two MPU6050 sensors produced unique signals that corresponded to various angles.

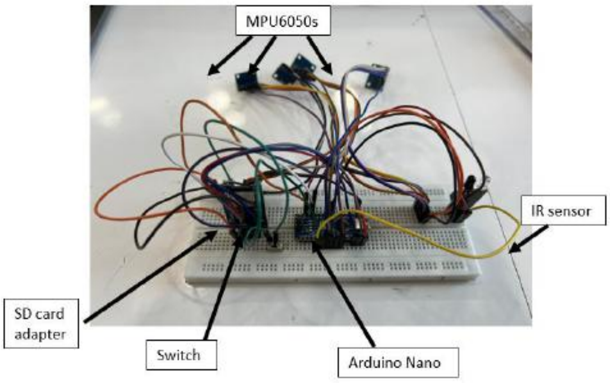

Fig1. 1st Prototype

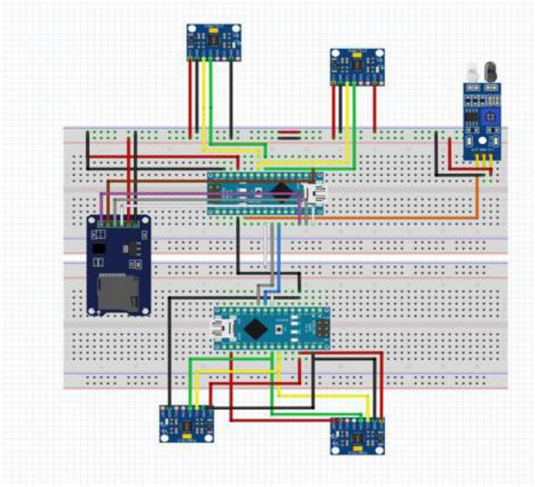

Fig 2. Connection Diagram

2) Block Diagram of Prototype

The research's essential elements and procedures are shown in these parts, each of which helps to build an embedded hardware system for real-time posture monitoring and cycling performance optimization.

1) 4 MPU (Motion Processing Units):

Four MPU sensors were used in this part of the research since they are crucial for gathering motion-related data. These sensors are essential for monitoring and evaluating the body positions and angles of the cyclist while they are riding.

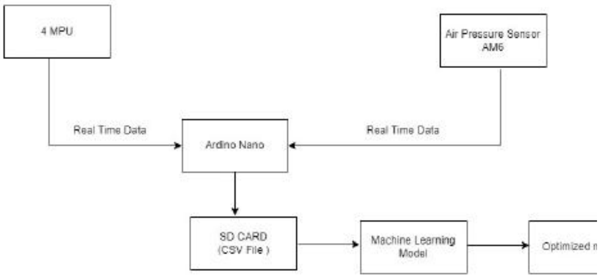

Fig 3. Block Diagram

2) Air Pressure Sensor AM6:

The AM6 differential pressure sensor was selected as the air pressure sensor of choice in order to measure air pressure in real time. The AM6 sensor was carefully assessed to make sure it was appropriate for this use. It is essential for collecting aerodynamic data that is needed to evaluate how air resistance affects cycling performance.

3) Arduino Nano:

This embedded hardware system's fundamental processing unit is the tiny but capable Arduino Nano microcontroller. It facilitates data collecting and analysis by establishing an interface with the air pressure sensor and the MPU sensors.

4) Data Saving into CSV File on SD Card:

A systematic system was put in place to record and store the important data produced by the sensors in the CSV (Comma-Separated Values) format. The obtained data can be subsequently evaluated or used for a variety of purposes thanks to this data-saving mechanism.

5) Optimization of MPU Data:

Data gathered from the MPU sensors was optimized as part of the investigation. The goal of the optimization procedure is to improve the precision and caliber of the data acquired from these sensors. This stage guarantees the accuracy of the motion-related data for subsequent examination.

6) Air Sensor Speed for Optimum Body Posture using KNN ML Model:

The K-nearest neighbours (KNN) model is an innovative machine learning model that was used to evaluate the cyclist's body posture and analyze air sensor data. This machine learning model is essential for giving the rider feedback in real time so they may modify their body posture and reduce air resistance while cycling.

3) Prototype Summary

Changes to the code were required due to early issues integrating SD card storage to capture IMU data in CSV format. With the main code section modified, the SD card was able to record data from the two MPU6050 sensors in CSV files. The experimental setup was completed by adding two more MPU6050 sensors. Nevertheless, issues with receiving inconsistent readings from these additional sensors emerged when they were rotated. To address this, a multipluxer was used to guarantee a range of readings from each of the four MPU6050 sensors.

After much research, a suitable pressure sensor for the project was also identified. After a thorough assessment, it was determined that the AMS5915 differential pressure sensor was appropriate for the task. To achieve accurate air pressure readings with the AMS5915 pressure sensor, a bell mouth attachment must be built on one of the tubes.

To sum up, the literature review covered a wide range of research, from the choice of pressure sensor to the fusion of several sensors and posture tracking with IMU sensors, providing a strong basis for the project.

C. *Machine Learning (KNN Model)*

In order to record the hand, head, and neck angles, we collected data using 4 MPU sensors and air pressure sensors.

Because of the size of the dataset, we have opted to employ the K-nearest neighbours (KNN) machine learning model. We investigated the effects of several scaling strategies on the KNN model's performance using cross-validation. By using cross-validation, we can determine whether the model has learned patterns from the training set of data rather than merely retaining samples, which would suggest overfitting. In this training set, the machine-learning model was trained to identify patterns, relationships, and structures. Since cross-validation is more suitable for some workloads and smaller datasets, we opted for it over a single train-test split. The dataset is partitioned into numerous subsets (folds) for cross-validation, with each fold being used for training and testing in turn. This method offers a more trustworthy evaluation of the model's performance, which may be especially useful when data is few. We chose K=5, which had the greatest performance when applied to the validation sets. The accuracy of the model was 85%.

VI. CONCLUSION

By shedding light on the intricate relationship between posture and cycling speed performance, this comprehensive study emphasizes the critical role that posture plays in determining a cyclist's speed capabilities. The study acknowledges the unavailability of a posture that is appropriate for all situations, but emphasizes the need for a balanced position that promotes muscle engagement, aerodynamics, and balance. The research offers a novel hardware solution that provides real-time aerodynamic data, allowing riders to quickly determine their ideal body position and speed and make smart adjustments to enhance their performance. The study's insights on air pressure measurements, sensor integration, and prototype creation further bolster its contributions to the field. In the areas of sports science, biomechanics, and physical training, this work essentially provides a strong foundation for further investigation and useful applications, bringing us one step closer to the possibility that cyclists can one day reach new heights of speed performance and realize their full potential.

In summary, this research work is unusual because it takes a comprehensive approach to improving cycling performance by integrating innovative sensors, collecting and analyzing data in real-time, and emphasizing environmental sustainability. This research is groundbreaking because it takes a comprehensive approach to riding posture and combines it with state-of-the-art technology.

A. *Application to Society*

The goal of the research is to help cyclists to reach their maximum speed while keeping a particular position that reduces discomfort and agony. Cycling enthusiasts may reach optimal performance without sacrificing their physical well-being by adjusting their posture.

VII. FUTURE SCOPE

The future of sports performance enhancement and cycling looks bright as long as technology keeps developing. Real-time data and analytics integration will enable athletes to push themselves to new heights of performance.

Application Outside of Cycling: Examine how this technology might be used in other sports and physical pursuits. Athletes participating in sports like jogging, swimming, and even motorsports might benefit from posture monitoring and aerodynamics adjustment.

Integration with Smart Wearables: A smooth and all-inclusive posture monitoring solution can be provided by integrating the system with smart wearables like suits and riding helmets. These devices provide real-time input, which can further improve a cyclist's performance.

Improved Data Analytics: This embedded hardware system's future is in more advanced data analytics. Deeper understanding of a cyclist's performance and posture can be obtained by putting sophisticated machine learning algorithms into practice. It is possible to anticipate posture changes for the best aerodynamics with predictive analytics.

Tailored Training Schedules: Create individualized training programs using the information gathered. Subsequent versions of the system may suggest particular workouts and modifications to enhance a cyclist's posture, muscular activation, and equilibrium.

Simulation and Training: Create virtual cycling simulations that allow cyclists to practice in various wind conditions and terrains. This will help in simulating real-world cycling situations and improving adaptability.

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REFERENCES

[1] Forte, P., Marinho, D. A., Barbosa, T. M., Morouço, P., & Morais, J. E. (2020). Estimation of an Elite Road Cyclist Performance in Different Positions Based on Numerical Simulations and Analytical Procedures. Frontiers in Bioengineering and Biotechnology, 8. https://doi.org/10.3389/fbioe.2020.00538

[2] Malizia, F., & Blocken, B. (2021). Cyclist aerodynamics through time: Better, faster, stronger. Journal of Wind Engineering and Industrial Aerodynamics, 214, 104673. https://doi.org/10.1016/j.jweia.2021.104673

[3] Kassim, A., Tayyeb, H., & Al-Falahi, M. (2020). Critical review of cyclist speed measuring techniques. Journal of Traffic and Transportation Engineering (English Edition), 7(1), 98-110. https://doi.org/10.1016/j.jtte.2019.09.001

[4] Yan, X., Ye, X., Chen, J., Wang, T., Yang, Z., & Bai, H. (2021). Bicycle Speed Modelling Considering Cyclist Characteristics, Vehicle Type and Track Attributes. World Electric Vehicle Journal, 12(1), 43. https://doi.org/10.3390/wevj12010043

[5] Ruiyan Li et al 2019 IOP Conf. Ser.: Mater. Sci. Eng. 688 022034 DOI 10.1088/1757-899X/688/2/022034

[6] Turpin, N. A., & Watier, B. (2019). Cycling Biomechanics and Its Relationship to Performance. Applied Sciences, 10(12), 4112. https://doi.org/10.3390/app10124112

[7] Hsiao, S., Chen, R., & Leng, W. (2015). Applying riding-posture optimization on bicycle frame design. Applied Ergonomics, 51, 69-79. https://doi.org/10.1016/j.apergo.2015.04.010