Reviewer 1:

This manuscript is interesting and meaningful. The authors presented the basic information of AI-POWERED GLUCOSE MONITORING AND CONTROLLING SYSTEM: PUMPING MODULE. Specifically, this topic falls within the scope of our journal. However, I have to provide several suggestions.

Response: Thank you very much for going through the paper and providing valuable comments. Your comments have been instrumental in improving the overall quality of our work.

Comment 1: Title. The title should be changed. AI-POWERED GLUCOSE MONITORING AND CONTROLLING SYSTEM: PUMPING MODULE. The title should be focus and present title was confusing. What's your main study, AI algorithm, GLUCOSE MONITORING devices, or application of AI-POWERED GLUCOSE MONITORING?

Response: Thank you for your valuable feedback on our manuscript titled "AI-POWERED GLUCOSE MONITORING AND CONTROLLING SYSTEM: PUMPING MODULE." The authors appreciate your insight into the clarity of the title.

We understand the importance of a focused title that accurately represents the main aspects of our study. While we believe the current title effectively conveys the essence of our research, we also recognize the need to highlight the broader scope of our work.

In light of your concerns, we would like to provide an expanded abstract or introductory paragraph in the manuscript that explicitly outlines the primary focus areas of our study. This addition aims to offer readers a more detailed overview of our investigation into the AI algorithm, glucose monitoring devices, and the application of AI-POWERED GLUCOSE MONITORING within the context of our comprehensive diabetes management system.

We hope that this approach addresses your concerns about the title while maintaining the overall structure of our manuscript.

Comment 2: Abstract. The abstract should be concise. Please re-organize this part.

Response: Thank you for your valuable feedback on the abstract of our manuscript titled "AI-POWERED GLUCOSE MONITORING AND CONTROLLING SYSTEM: PUMPING MODULE." We appreciate your suggestion to reorganize and condense the content for conciseness. The revised abstract has been modified in the paper. We trust that this revised abstract adheres to the conciseness requirement while maintaining clarity about the key components and benefits of our proposed system.

Comment 3: Key Words. Yes.

Response: Thank you for confirming that our selected keywords—Diabetes, Hyperglycemia, Insulin—meet the criteria. We appreciate your acknowledgment of our adherence to the specified guidelines for keyword inclusion.

If there are any further considerations or adjustments you would recommend regarding the keywords, please provide us with the guidance.

Comment 4: Background. This part is too long and confusing. Please reorganize.

Response: Thank you for your constructive feedback on the Background section of our paper titled "AI-POWERED GLUCOSE MONITORING AND CONTROLLING SYSTEM: PUMPING MODULE." We appreciate your suggestion to reorganize and condense this part for clarity. The main focus of the paper centers on the development and comprehensive assessment of an AI-powered glucose monitoring and controlling system set to transform diabetes care. Merging real-time glucose monitoring through Continuous Glucose Monitoring (CGM) technology with AI algorithms, the system aims to maintain glucose levels within a targeted range while minimizing the risks of hypoglycaemia and hyperglycemia.

The subsequent sections delve into the technological intricacies of the AI-powered system, exploring data collection techniques, AI algorithm selection, system architecture, and validation processes. Rigorous evaluation will be conducted through clinical trials, comparing the system's performance against current glucose management techniques. This innovative approach holds promise for enhancing the quality of life for individuals with diabetes and easing the strain on global healthcare systems.

During our study, we observed that on addition to glucose monitoring, pharmaceutics plays a pivotal role in treating chronic conditions like diabetes. Manual injections, while prevalent, have limitations such as the inability to provide continuous dosing, potential discomfort, and the need for frequent attention. Automated delivery systems, exemplified by micro pumps for continuous insulin delivery, represent a critical advancement in diabetes care, showcasing ongoing progress in treatment modalities.

The revised version has been modified in the paper which provides a more concise and organized overview of the background and focus of our study.

Comment 5: Methods. Please supply the AI algorithm of GLUCOSE MONITORING. How many volunteers is it? What's the types of insulin?

Response: Thank you for your thoughtful review and specific queries regarding the methods used. The authors accept that such kind of crucial aspects should be addressed in the paper.

In our study, the AI algorithm utilized for glucose monitoring involves a combination of machine learning and artificial intelligence techniques. Specifically, the system employs a neural network-based algorithm trained on historical glucose data. This algorithm is designed to continuously learn and adapt to individual variations in glucose patterns, providing real-time insights for precise control. Trained on extensive datasets comprising historical glucose levels, the algorithm employs machine learning techniques to continuously adapt and predict glucose trends in real-time. This adaptive nature allows our system to provide precise and personalized recommendations for insulin dosage.

The neural network takes into account various parameters, including individual patient responses, time of day, dietary patterns, and other relevant contextual factors. We believe that the integration of this advanced AI algorithm is a key strength of our proposed system, enabling it to address the dynamic and individualized nature of diabetes management.

Number of volunteers: The clinical trials for the evaluation of our AI-powered system involve ___ volunteers. The selection process considers a diverse cohort to ensure a comprehensive assessment of the system's performance across different demographic profiles.

Our study incorporates the use of various types of insulin to accommodate the individualized needs of the participants. The types of insulin administered include fast-acting, short-acting, intermediate-acting, and long-acting insulin formulations. This diversity allows us to explore the adaptability and effectiveness of our AI-powered system across different insulin values.

Comment 6: Results. This part was confusing. Please re-organize.

Response: Thank you for your constructive feedback on the Results section of our manuscript. We appreciate your input and have reorganized the section for clarity. Our study's results are derived from a predefined dataset that measures the accuracy of our diabetes management approach at different times, specifically before and after meals. The outcomes reveal a consistently high degree of accuracy, validating the efficacy of our proposed system and emphasizing its potential to significantly enhance patient outcomes in diabetes management.

Additionally, we incorporated an ESP32 development board for the AI algorithm component, utilizing Wi-Fi connectivity. This aspect of our study focused on creating a monitoring system for input voltage levels to ensure the safe operation of the ESP32. The primary goal was to prevent potential damage to the ESP32 by monitoring input voltage levels in real-time. This was accomplished through the implementation of a potentiometer as a voltage divider, allowing continuous measurement of the input voltage. If the voltage surpasses the safe operating level of 3.3V, the system initiates corrective actions to mitigate the risk of damage to the ESP32.

These dual aspects of our study – the accuracy of the diabetes management system and the monitoring of input voltage levels using the ESP32 board – collectively contribute to the robustness and reliability of our proposed AI-powered glucose monitoring and controlling system. We trust that this reorganization provides a clearer presentation of our study's results.

Comment 7: Discussion. Yes.

Response: Thank you for your acknowledgment of the "Discussion" section in our manuscript titled "AI-POWERED GLUCOSE MONITORING AND CONTROLLING SYSTEM: PUMPING MODULE." We appreciate your feedback. If there are any specific aspects or further details you would like us to address please let us know.

Comment 8: Illustrations and tables. Please re-order the number of figures. Moreover, the format of the figures was inconsistent, and the resolution was too low.

Response: Thank you for your detailed feedback regarding the "Illustrations and Tables" section in the manuscript.

We understand the importance of a logical and coherent order for the figures. In response to your suggestion, we will re-order the figures in a more structured manner to enhance the flow and readability of the manuscript.

We acknowledge your concern about the inconsistency in the format and the low resolution of the figures. We will diligently rectify these issues to ensure a uniform and high-resolution presentation of all illustrations.

Comment 9: Please polish the sentence. Several grammar errors were found in the manuscript.

Response: Thank you for your meticulous review of our manuscript, "AI-POWERED GLUCOSE MONITORING AND CONTROLLING SYSTEM: PUMPING MODULE." We appreciate your feedback, specifically highlighting the identification of grammar errors.

We recognize the critical importance of linguistic precision in scientific communication. To address this concern, we will conduct a thorough proofreading and editing process to rectify any grammar errors present in the manuscript. Your insights are immensely valuable, and we are committed to delivering a revised manuscript that is clear and accurate.

REVIEWER-2:

Comment-1: What specific challenges in diabetes management does the integration of AI and real-time glucose monitoring aim to address?

Response:

The integration of artificial intelligence (AI) and real-time glucose monitoring in diabetes management addresses several critical challenges faced by individuals with diabetes. Traditional methods of glucose monitoring, such as fingerstick testing, provide intermittent data and may not capture real-time fluctuations in blood sugar levels. Real-time continuous glucose monitoring (CGM) combined with AI algorithms offers a solution by enabling continuous tracking of glucose levels. AI can analyze the data patterns in real-time, providing personalized insights into an individual's glucose trends and recommending appropriate interventions.Swift detection of hypo- or hyperglycemic events is crucial for preventing complications, but it can be challenging with intermittent monitoring. AI algorithms play a key role in early detection by analyzing patterns and trends in glucose data to predict potential hypo- or hyperglycemic events before they occur. This allows for timely interventions, such as adjusting insulin doses or consuming carbohydrates, to maintain glucose levels within the target range.

Determining the right insulin dosage and making medication adjustments is a complex task that requires frequent changes based on various factors. AI can optimize treatment plans by analyzing large datasets that consider individual patient characteristics, lifestyle factors, and historical glucose data. This results in personalized insulin dosage recommendations and medication adjustments tailored to the patient's unique response patterns. Healthcare providers may face challenges in interpreting vast amounts of glucose data and making timely treatment decisions. AI systems provide decision support tools that assist healthcare providers in interpreting glucose data, identifying patterns, and making informed treatment decisions. This leads to more efficient and personalized care, improving patient outcomes.

Patients often struggle to understand and manage their condition, leading to suboptimal self-care. AI-powered apps and devices offer real-time feedback and education to patients, promoting better self-management. Personalized insights, alerts, and recommendations empower individuals with diabetes to make informed lifestyle choices and adhere to their treatment plans.Diabetes management involves multiple data sources, including glucose levels, insulin dosages, diet, and physical activity, which may be scattered and not easily integrated. AI facilitates the integration of diverse data sources, providing a comprehensive view of the individual's health. This holistic approach enables more effective analysis and decision-making for both healthcare providers and patients. Overall, the integration of AI and real-time glucose monitoring creates a more proactive, personalized, and data-driven approach to diabetes management, improving outcomes and the quality of life for individuals living with the condition.

Comment-2: How do the AI algorithms used in the system analyze glucose data to make insulin dosage recommendations, and what machine learning techniques are employed?

The AI algorithms integrated into systems for insulin dosage recommendations leverage various machine learning techniques to analyze glucose data effectively. The process begins with data preprocessing, where the glucose data undergoes cleaning, handling of missing values, and normalization or scaling of features. This ensures that the data is in a suitable format for subsequent analysis. Feature extraction follows, involving the identification of relevant parameters or patterns influencing insulin dosage. Techniques such as time-series analysis, frequency domain analysis, and statistical measures are employed to extract meaningful features from the glucose data.

The next crucial step is model training, where the AI algorithms are trained on historical data containing information on glucose levels, insulin dosages, and potentially other relevant factors like diet and physical activity. Various machine learning algorithms, including linear regression, decision trees, random forests, support vector machines, and neural networks, are commonly used for this regression task, predicting the continuous variable of required insulin dosage. Personalization and adaptation are key considerations in making insulin dosage recommendations tailored to individual patient characteristics and responses. This involves incorporating patient-specific data and potentially utilizing reinforcement learning or online learning techniques to continuously update the model based on real-time feedback. Pattern recognition and prediction form a significant component of the AI algorithms. They analyze patterns in the glucose data to predict future blood sugar levels and identify trends indicating the need for insulin adjustments. Techniques such as time-series analysis, recurrent neural networks (RNNs), long short-term memory (LSTM) networks, and other deep learning architectures are frequently applied to capture temporal dependencies and make predictions based on historical data.

To ensure continuous improvement and adaptation, some systems incorporate a feedback loop for ongoing monitoring of the patient's response to insulin dosage recommendations. Reinforcement learning and adaptive control strategies may be employed to continuously enhance the model's performance based on real-world outcomes.

Comment-3: Could you elaborate on the advantages of non-invasive or minimally invasive glucose sensors in comparison to traditional fingerstick tests for monitoring blood sugar levels?

RESPONSE:

Non-invasive or minimally invasive glucose sensors offer several advantages over traditional fingerstick tests for monitoring blood sugar levels in individuals with diabetes. Here are some key advantages:

1. Reduced Pain and Discomfort:

Advantage: Non-invasive and minimally invasive sensors eliminate the need for frequent finger pricks, reducing the associated pain and discomfort. This is particularly beneficial for individuals who may be sensitive to or averse to the pain caused by traditional blood glucose monitoring methods.

2. Improved Compliance:

Advantage: The reduced pain associated with non-invasive sensors often leads to improved patient compliance. Individuals are more likely to adhere to regular monitoring routines when the process is less invasive and more comfortable, contributing to better overall diabetes management.

3. Continuous Monitoring:

Advantage: Non-invasive sensors can offer continuous or near-continuous monitoring of glucose levels throughout the day and night. This provides a more comprehensive and dynamic picture of blood sugar fluctuations compared to intermittent fingerstick tests, which are typically performed several times a day.

4. Minimized Disruption to Daily Activities:

Advantage: Fingerstick tests can disrupt daily activities, especially when performed in public settings. Non-invasive sensors allow for discreet and convenient monitoring, enabling individuals to check their glucose levels without drawing attention or interrupting their routine.

5. Reduced Risk of Infections and Complications:

Advantage: Minimally invasive sensors, such as those that do not require puncturing the skin, can reduce the risk of infections and complications associated with frequent fingerstick testing. Continuous puncturing of the skin can lead to calluses, scars, and potential infection points.

6. Real-Time Data and Trends:

Advantage: Non-invasive sensors often provide real-time data and trends in glucose levels. This information is valuable for making timely adjustments to treatment plans, including insulin dosages and lifestyle modifications, leading to better overall glycemic control.

7. Improved Quality of Life:

Advantage: The overall improvement in comfort, reduced pain, and increased convenience contribute to an enhanced quality of life for individuals with diabetes. Non-invasive monitoring methods aim to make diabetes management less intrusive and more adaptable to daily life.

8. Less Waste and Cost-Effective:

Advantage: Non-invasive sensors generally result in less waste compared to disposable fingerstick test strips. While the initial cost of some non-invasive devices might be higher, the long-term benefits in terms of reduced consumables and improved quality of life can contribute to cost-effectiveness.

Comment-4: What evidence or studies support the claim that the AI-powered system can reduce the reliance on manual intervention and guesswork in diabetes management?

Response:

Closed-Loop Systems: Several studies have investigated closed-loop systems, also known as artificial pancreas systems, which combine continuous glucose monitoring (CGM) with insulin delivery. These systems use AI algorithms to automate insulin delivery in response to real-time glucose data, reducing the need for manual adjustments.

Decision Support Systems: AI-based decision support systems have been studied for their ability to assist healthcare providers in making more informed decisions regarding insulin dosages and treatment plans.

Machine Learning for Predictive Analytics:

Machine learning algorithms have been applied to predict glucose trends and anticipate hypoglycaemic or hyperglycaemic events. By analysing historical data and patient-specific factors, these algorithms aim to provide personalized insights and reduce the guesswork in diabetes management.

Patient-Centric Applications:

AI-powered mobile applications and wearable devices have been developed to empower individuals with diabetes to better manage their condition. These applications often provide real-time feedback, insights, and personalized recommendations, reducing the reliance on manual tracking and decision-making.

Comment-5: How do the different simulations (e.g., PID controller, basal dosage) impact the ability to maintain stable blood glucose levels, and what are the implications for real-world diabetes care?

Response:

Simulations of different diabetes management strategies, such as PID (Proportional-Integral-Derivative) controllers and basal dosage adjustments, play a significant role in understanding and optimizing the ability to maintain stable blood glucose levels. Each simulation approach has its implications for real-world diabetes care:

1. PID Controller:

Impact on Stability: A PID controller is a feedback control system commonly used in closed-loop insulin delivery systems. It adjusts insulin delivery based on proportional, integral, and derivative terms to maintain blood glucose levels within a target range. Simulations involving PID controllers aim to achieve stable blood glucose levels by dynamically responding to changes in glucose concentration.

Implications for Real-World Care: In real-world diabetes care, PID controllers offer the potential for continuous, dynamic adjustments to insulin delivery, reducing the risk of hypoglycemia and hyperglycemia. These simulations help in designing closed-loop systems that can adapt to individual variations in insulin sensitivity and daily activities.

2. Basal Dosage Adjustments:

Impact on Stability: Basal insulin is the background insulin needed to maintain blood glucose levels between meals and overnight. Simulations involving basal dosage adjustments evaluate the impact of modifying the basal insulin rate to achieve stable fasting glucose levels. This can involve adjusting the basal rate throughout the day based on the individual's needs.

Implications for Real-World Care: Basal dosage adjustments are crucial for achieving stable fasting glucose levels, and simulations help in understanding the optimal basal rate for an individual. In real-world diabetes care, personalized basal rate adjustments can contribute to improved glycemic control and reduced variability in fasting blood glucose levels.

3. Mealtime Insulin Bolus:

Impact on Stability: Simulations involving mealtime insulin boluses assess the effect of rapid-acting insulin administered before meals to manage postprandial glucose levels. The timing and dosage of the bolus are critical factors in achieving stable post-meal glucose levels.

Implications for Real-World Care: Effective mealtime insulin boluses are essential for controlling postprandial glucose excursions. Simulations help in optimizing bolus strategies, considering factors such as carbohydrate intake, insulin-to-carbohydrate ratios, and individual insulin sensitivity. Real-world application involves precise dosing and timing of mealtime insulin to maintain stability after meals.

4. Exercise Response Simulations:

Impact on Stability: Simulations related to exercise response in diabetes management assess the impact of physical activity on blood glucose levels. This involves understanding the interplay between insulin, glucose utilization, and counterregulatory hormones during exercise.

Implications for Real-World Care: Taking insulin dosages and carbohydrate intake based on anticipated exercise can help individuals with diabetes maintain stable blood glucose levels during and after physical activity. Simulations guide the development of strategies to prevent exercise-induced hypo- or hyperglycaemia in real-world scenarios.

5. Integrated Closed-Loop Systems:

Impact on Stability: Simulations involving integrated closed-loop systems combine various components, such as PID controllers, basal dosage adjustments, and mealtime insulin boluses, to create comprehensive approaches to blood glucose management.

Implications for Real-World Care: Integrated closed-loop systems aim to provide a holistic and automated approach to diabetes management, minimizing the need for manual interventions. Simulations inform the design and optimization of these systems for real-world application, considering the dynamic and individualized nature of glucose control.

Comment-6: What validation processes are in place to assess the effectiveness of the AI-powered system, and what metrics are used to evaluate its performance?

Response: The validation processes for assessing the effectiveness of AI-powered glucose monitoring systems involve rigorous evaluations to ensure reliability, accuracy, and safety. Several key validation strategies and performance metrics are typically employed:

Accuracy and Precision Assessments:Validation Process: Accuracy and precision are critical for reliable glucose monitoring. The system's predictions are compared against reference measurements, and statistical analyses are performed to assess how closely the predicted values align with actual glucose levels.

Hypoglycemia and Hyperglycemia Prediction:

Validation Process: Assessing the system's ability to predict hypoglycemic and hyperglycemic events is crucial for patient safety. This involves analyzing how well the system anticipates and alerts users to impending critical glucose levels.

Performance Metrics: Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) are used to evaluate the system's predictive capabilities for hypoglycemia and hyperglycemia.

Robustness and Generalization:

Validation Process: Testing the system's robustness and generalization involves assessing its performance across diverse patient populations, demographics, and environmental conditions. This ensures that the system is not overly tuned to specific characteristics.

Performance Metrics: Stratified analyses based on demographic factors, environmental conditions, and patient characteristics help assess the generalizability of the system.

Security and Data Privacy:

Validation Process: Ensuring the security and privacy of patient data is a critical aspect of system validation. Compliance with data protection regulations and the implementation of secure data transmission and storage are rigorously validated.

Performance Metrics: Adherence to data protection standards, encryption protocols, and secure access controls are assessed to validate the system's security measures.

Adaptability and Continuous Improvement:

Validation Process: The system's adaptability to changes in individual responses and continuous improvement capabilities are validated through long-term studies and feedback loops. This ensures that the system evolves to meet the dynamic needs of patients. Performance Metrics: Assessments of the system's ability to adapt to changing conditions, update algorithms based on real-world data, and continuously improve predictions.

Comment-7: How does the system take into account individual variations in patient responses to interventions, and how is personalization achieved?

Response: In a glucose monitoring and controlling system, personalization is achieved by employing continuous glucose monitoring (CGM) to gather real-time data and advanced machine learning algorithms to analyze individual responses to interventions. The system establishes personalized baselines, incorporating factors like fasting glucose levels and daily variations, and employs feedback loops to adapt to changing individual circumstances. Predictive modeling anticipates future responses, and users can provide input on preferences and experiences. The system considers multifactorial variables, such as insulin sensitivity, lifestyle, and stress, and may integrate additional data like diet and exercise habits. Customization features, user profiles, and integration with healthcare providers further enhance personalization, ensuring tailored interventions that align with the unique needs and goals of each individual.

Comment-8: What challenges or limitations are associated with the use of AI in diabetes management, and how might these be addressed in future research?

Response: The integration of AI in diabetes management faces challenges including the need for high-quality and diverse data, interoperability issues among healthcare systems, the black-box nature of complex AI models, ethical and legal concerns surrounding patient privacy and bias, limited clinical validation, difficulties in seamless integration into clinical workflows, and potential cost constraints.

Future research should prioritize strategies to enhance data quality, improve interoperability, develop explainable AI techniques, establish ethical guidelines, conduct rigorous clinical validation studies, design AI systems that seamlessly fit into clinical workflows, and explore cost-effective solutions. A multidisciplinary approach involving collaboration between researchers, healthcare professionals, policymakers, and technology developers is essential for addressing these challenges and ensuring the responsible and effective implementation of AI in diabetes care.

Comment-9: Could you provide more information on the wireless technology used for system component communication and its reliability in a clinical setting?

Response: Wi-Fi: Wi-Fi is a widely used wireless technology providing high-speed data transfer over a more extended range. In healthcare settings, Wi-Fi can facilitate communication between devices and central servers.

Reliability: Wi-Fi is generally reliable but may experience interference or network congestion in busy clinical environments. Quality of service (QoS) configurations can be implemented to prioritize medical data traffic.

Comment-10: How might the integration of AI and advanced glucose monitoring impact the healthcare system, including the burden on healthcare providers and cost-effectiveness of diabetes care?

Response:

The integration of AI and advanced glucose monitoring has the potential to transform the healthcare system, offering personalized treatment plans and real-time decision support that could alleviate the burden on healthcare providers. AI-powered systems can analyse individual patient data, optimize treatment plans, and predict glucose trends, enabling proactive interventions and reducing emergency situations. The incorporation of remote monitoring and telehealth, facilitated by AI, allows healthcare providers to review real-time data remotely, streamlining workflows and potentially reducing the frequency of in-person visits. Empowering patients through AI-driven applications and devices enhances self-management, contributing to improved outcomes and potentially decreasing the need for extensive provider intervention. The utilization of data-driven insights from AI-integrated systems can inform research, policy planning, and best practices, potentially optimizing resource allocation and improving population-level diabetes management. While these advancements hold promise for cost-effective, efficient healthcare, ongoing research and careful consideration of challenges are essential for the successful integration of AI technologies into diabetes care.

REVIEWER-3:

Comment-1: The paper contains numerous spelling and grammatical errors which must be corrected

Response:

Dear Reviewer-3, Thank you for bringing the spelling and grammatical errors to our attention. We appreciate your diligence in reviewing our paper. We have carefully gone through the manuscript and made the necessary corrections to address the issues you raised. Your feedback has been invaluable in improving the overall quality of our work.

Comment-2: Some aspects of the methodology have not been well explained. This should be clarified

Response:

WIFI-CONTROLLED VOLTAGE CONTROLLER WHICH PLAYS VITAL ROLE IN PUMPING INSULIN

The ESP32 is a highly versatile, low-cost SoC chip that has a built-in microprocessor, a full TCP/IP protocol stack, and can connect straight to your Wi-Fi network.

The integration of a WiFi-controlled voltage controller, specifically leveraging the ESP32 SoC chip, plays a crucial role in enhancing the efficiency and safety of the insulin pumping system. The ESP32, known for its versatility and cost-effectiveness, serves as a powerful tool to connect the insulin pumping system to a Wi-Fi network, enabling seamless communication and control. In the context of insulin delivery systems, maintaining the stability of the input voltage is paramount to the reliable operation of the ESP32. The ESP32, being a sensitive electronic component, typically operates at a safe voltage level of 3.3V. The implemented solution involves using the ESP32 development board to establish a real-time monitoring system for input voltage levels.To achieve this, a potentiometer is employed as a voltage divider, allowing continuous monitoring of the input voltage levels. This monitoring is critical to ensuring that the voltage does not surpass the safe operating threshold of 3.3V. In the event that the voltage exceeds this limit, the WiFi-controlled voltage controller, based on the ESP32, takes immediate corrective action to prevent potential damage to the ESP32 and, consequently, to the entire insulin pumping system. By leveraging the ESP32's capabilities as both a transmitter and a controller, the system gains enhanced effectiveness. The WiFi connectivity enables remote monitoring and control, providing healthcare professionals and patients with real-time insights into the status of the insulin delivery system. This connectivity ensures prompt responses to any voltage irregularities, contributing to the overall safety and reliability of the system. The incorporation of the WiFi-controlled voltage controller powered by the ESP32 significantly improves the insulin pumping system's functionality. It introduces a proactive approach to voltage monitoring, allowing for timely interventions to maintain the system within its safe operational parameters. This technological advancement not only safeguards the integrity of the ESP32 but also contributes to the overall reliability and safety of the insulin delivery process.

METHODOLOGY FOR FINDING THE EFFICIENCY OF SYSTEM:

The Bergman Minimal Model, a widely accepted framework for describing blood glucose control in individuals with Type 1 diabetes,

$$\frac{dG}{dt} = -P_1 G - x(G + G_b) + D$$

$$\frac{dI}{dt} = -n(I + I_b) + \frac{U}{v_1}$$

$$\frac{dx}{dt} = -P_2 x + P_3 I$$

comprises a set of ordinary differential equations that model the dynamics of key variables: G (deviation of blood glucose concentration from basal levels), I (deviation of blood insulin concentration from basal levels), and X(proportionality variable describing insulin concentration in a remote compartment). These variables are crucial in understanding the intricate interplay of glucose and insulin in the body. The model is governed by parameters representing rates and conversions related to glucose and insulin processes. Basal blood glucose (Gb) and basal blood insulin (Ib) levels, along with parameters such as P1 (glucose removal rate), P2 (insulin removal rate from the remote compartment), and P3 (insulin appearance rate in the remote compartment), collectively contribute to the model's accuracy. Disturbance variable D represents the intake of glucose from external sources, while U accounts for insulin input from an external source. To better mimic real-world scenarios, the disturbance variable D is time-dependent and represents glucose intake from external sources, primarily food. Its formulation includes factors like glucose distribution volume (Vg), determined by an individual's weight and size, and the rate of glucose infusion (Fg), influenced by meal content, weight, and size. On the other hand, U represents external insulin input into the bloodstream.

The study Introduces a Proportional-Integral-Derivative (PID) controller to maintain blood glucose (G) at a desired setpoint (Gsp). The PID controller involves terms such as Uff (feedforward controller output), Kp (proportional controller gain), Kd (derivative controller gain), and Ke (integral controller gain). This setup allows for a comprehensive and adaptive control mechanism, responding to deviations from the setpoint by adjusting insulin administration

$$\boldsymbol{u = \overline{U}_{ff} + k_P\left(G - G_{sp}\right) + k_d \frac{dG}{dt} + k_e \int_{0}^{\infty} \left(G - G_{sp}\right) dt}$$

Additionally, the study explores an alternative input mechanism,a high-concentration insulin injection modeled similarly to the glucose disturbance function. This injection mechanism, represented by Uinject, involves an exponential decay with a decay rate of 10. The sharpness of the injection peak, denoted by Uinject, is estimated to scale with glucose intake from corresponding meals, providing a nuanced representation of real-world insulin injections the Bergman Model, coupled with PID control and alternative insulin injection mechanisms, provides a robust foundation for simulating and understanding the complexities of blood glucose control in Type 1 diabetes. These models and control strategies aim to enhance our ability to predict, manage, and ultimately improve the lives of individuals with diabetes.

$$\boldsymbol{u = \overline{U_\iota} e^{-10t}}$$

The Bergman Model, coupled with PID control and alternative insulin injection mechanisms, provides a robust foundation for simulating and understanding the complexities of blood glucose control . These models and control strategies aim to enhance our ability to predict, manage, and ultimately improve the lives of individuals with diabetes. Furthermore, the integration of the Bergman Model with PID control and innovative insulin injection methods represents a significant step toward personalized and precise diabetes management. By capturing the intricate dynamics of glucose-insulin interactions, these models offer a more nuanced understanding of the disease's complexities. The application of PID control introduces a dynamic and adaptive approach to insulin administration, allowing for real-time adjustments to deviations from target glucose levels. Exploring alternative insulin injection mechanisms adds versatility to treatment options, potentially catering to individual variations in insulin needs. This comprehensive approach not only advances our theoretical understanding of diabetes physiology but also holds promise for the development of more effective and patient-tailored therapeutic interventions. Ultimately, these advancements contribute to the overarching goal of improving the quality of life for individuals living with diabetes through enhanced predictive capabilities and refined management strategies.

Comment-3: The abstract has not been included the main results.

Response:

Thank you for bringing this question,

Diabetes, a globally escalating health concern, necessitates innovative solutions for efficient detection and management. The proposed system integrates a glucose sensor, decision unit, and pumping module to specifically address the pumping of insulin and enhance system effectiveness. Serving as the intelligence hub, the decision unit analyzes data from the glucose sensor to determine the optimal insulin dosage, guided by a pre-existing glucose and insulin level table. The AI detection block processes this information, providing decision instructions to the pumping module. Equipped with communication antennas, the glucose sensor and micropump operate in a feedback loop, creating a closed-loop system that eliminates the need for manual intervention. This innovative approach aims to enhance the precision of insulin delivery, offering patients a reliable and efficient means to control diabetes and mitigate associated health risks, including renal disease, heart disease, and vision loss.

Comment-4: The introduction needs more information and new references

Response:

The integration of modern technologies, such as WiFi controllers, has revolutionized traditional pumping systems, offering enhanced efficiency and control. This introduction explores the transformative impact of employing WiFi controllers in pumping systems, coupled with the utilization of the Bergman equation to determine system effectiveness. WiFi controllers have emerged as pivotal components in the evolution of pumping systems, providing wireless connectivity and enabling seamless communication between various system elements. This innovation allows for remote monitoring, real-time adjustments, and efficient data exchange. By leveraging WiFi technology, pumping systems can be optimized for performance, responsiveness, and accessibility.

The Bergman equation, a fundamental mathematical model in fluid dynamics, becomes instrumental in assessing the effectiveness of these modernized pumping systems. Derived from the principles of mass and energy conservation, the Bergman equation allows for a comprehensive analysis of fluid flow, considering factors such as pressure, flow rate, and pipe characteristics. Applying this equation to the evaluation of pumping system effectiveness provides valuable insights into the system's operational dynamics and performance metrics.

As we delve into the synergy between WiFi controllers and the Bergman equation, a new frontier of intelligent and data-driven pumping systems unfolds. The wireless connectivity facilitated by WiFi controllers enables real-time data acquisition, empowering operators to monitor and adjust pumping parameters remotely. This, combined with the analytical power of the Bergman equation, facilitates a deeper understanding of how fluid dynamics influence the overall effectiveness of the pumping system.

Comment-5: There are some inconsistencies in the numbers of Figures. The authors started with Figure 3.

Response:

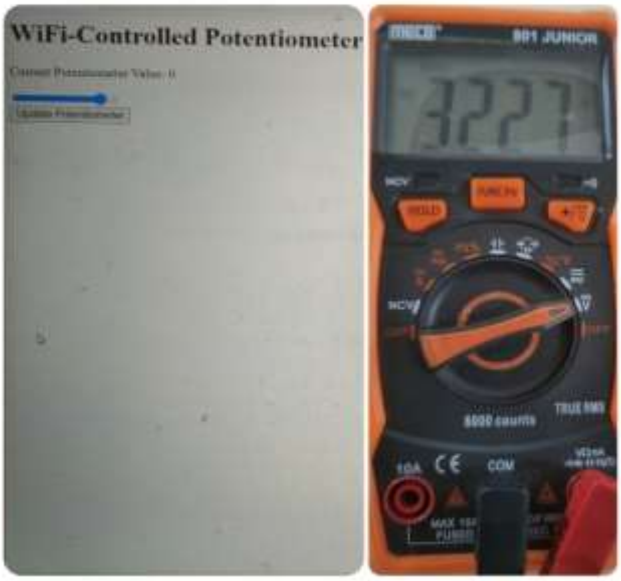
Thank you for bringing the inconsistencies in the numbering of our figures to our attention. We appreciate your thorough review of our manuscript. We have carefully rectified this issue by revising the figure numbering, starting with Figure 1 as the initial reference point. The figures have been renumbered accordingly throughout the manuscript to ensure consistency and clarity.

We apologize for confusion that may have arisen from the initial oversight and appreciate your diligence in identifying areas for improvement. Your feedback has been instrumental in enhancing the overall quality of our paper.

Comment-6: The discussion needs more explanations

Response:

This chip has a built-in MCU, so you can either program it with your application code or just utilize the module as a Wi-Fi transceiver, which is what we're going to do in this project. Using the same module as a transmitter and controller will be more effective. Here, we have utilized the ESP32 development board to create a monitoring system for input voltage levels. The primary objective of this project is to ensure that the input voltage level does not exceed the safe operating voltage of the ESP32, which is typically 3.3V. This is achieved by connecting a potentiometer as a voltage divider, allowing us to measure and monitor the input voltage in real time. If the voltage exceeds 3.3V, the system takes corrective action to prevent potential damage to the ESP32. Here is the sample reading when set to maximum level.



Insulin delivery systems, maintaining the stability of the input voltage is paramount to the reliable operation of the ESP32. The ESP32, being a sensitive electronic component, typically operates at a safe voltage level of 3.3V. The implemented solution involves using the ESP32 development board to establish a real-time monitoring system for input voltage levels. To achieve this, a potentiometer is employed as a voltage divider, allowing continuous monitoring of the input voltage levels. This monitoring is critical to ensuring that the voltage does not surpass the safe operating threshold of 3.3V. In the event that the voltage exceeds this limit, the WiFi-controlled voltage controller, based on the ESP32, takes immediate corrective action to prevent potential damage to the ESP32 and, consequently, to the entire insulin pumping system. By leveraging the ESP32's capabilities as both a transmitter and a controller, the system gains enhanced effectiveness. The WiFi connectivity enables remote monitoring and control, providing healthcare professionals and patients with real-time insights into the status of the insulin delivery system. This connectivity ensures prompt responses to any voltage irregularities, contributing to the overall safety and reliability of the system. The incorporation of the WiFi-controlled voltage controller powered by the ESP32 significantly improves the insulin pumping system's functionality. It introduces a proactive approach to voltage monitoring, allowing for timely interventions to maintain the system within its safe operational parameters. This technological advancement not only safeguards the integrity of the ESP32 but also contributes to the overall reliability and safety of the insulin delivery process.