

## IOT based Glucoguardian for ICU patients

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### Abstract

In the current era of rapid technological advancement, healthcare systems are increasingly adopting smart technologies to improve patient safety. Intravenous (IV) glucose administration is critical in ICU and emergency care, yet manual monitoring often leads to errors like over-infusion or delayed responses to empty bottles. This paper proposes *Glucoguardian*, an IoT-based system that automates the monitoring and control of IV glucose. Utilizing an ESP32 microcontroller with flow and level sensors, the system ensures precise delivery via a solenoid valve. Real-time data and alerts are transmitted to a cloud platform for remote supervision. By reducing human error and improving administration accuracy, this solution demonstrates the transformative potential of IoT in modern healthcare.

**Keywords**— Internet of Things (IoT), Glucose Monitoring System, ESP32 Microcontroller, Intravenous Infusion, Healthcare Monitoring, Solenoid Valve Control.

### 1. Introduction

The core concept of this project is to monitor the glucose level in intravenous (IV) bottles and provide timely alerts to healthcare staff using an automated system. The proposed system, *Glucoguardian*, is designed to continuously track the level of glucose in the bottle to ensure uninterrupted flow to the

patient. The parameters considered in this system include the glucose level in the bottle, flow status, and alert notifications when the level becomes low or empty. By incorporating sensor technology and microcontroller-based monitoring, the system aims to reduce the need for manual supervision by nurses. This automated monitoring approach improves accuracy and helps prevent risks associated with delayed bottle replacement. In many hospitals, the glucose level is still checked manually, which may lead to human error or delayed response. Therefore, this system provides an efficient and reliable solution to assist healthcare staff and improve patient safety during glucose administration.

### 2 . Related Work

In the coming decades, healthcare infrastructures will be required to manage higher patient volumes with limited clinical staff, necessitating a shift toward automated surveillance. This study, conducted by Karthik et al. [1], quantifies the effectiveness of a weight-based monitoring framework on patient safety, utilizing data gathered through ESP32-integrated sensing. It considers the impacts of human fatigue and the limitations of manual observation on intravenous (IV) therapy outcomes—specifically the risks of air embolism and blood backflow—while concurrently evaluating the benefits of technological advancements in load-cell precision and wireless alert broadcasting. The analysis employs a hardware-software co- design to assess how real-time weight tracking influences the reliability of fluid level detection.

Simulations and clinical prototypes of the IoT monitoring model indicate that the integration of the HX711 weighing module leads to a significant increase in data accuracy compared to traditional manual estimation. The system is projected to enhance response times by utilizing the Thing Speak cloud platform and Telegram API to transmit instant notifications to healthcare providers. While the use of an ESP32 microcontroller significantly affects the energy efficiency and portability of the device, the automated broadcasting of alerts contributes the most to reducing the overall workload of frontline medical workers. Adjustments in the weight-sensing threshold can either amplify or diminish the impact of remote monitoring, ultimately demonstrating the vital role of the Internet of Things in preventing complications in high-stress medical environments. [1]

Modern healthcare infrastructures increasingly prioritize integrated hardware and software solutions to eliminate the risks associated with manual intravenous (IV) administration, such as incorrect dosages and delayed responses to fluid depletion. This study, conducted by Venkat S et al., evaluates the effectiveness of an intelligent monitoring system that utilizes specialized sensors to track fluid flow rates, remaining volume, and system pressure in real-time. The research considers the impacts of periodic manual checks—which often result in delayed detection of patient condition changes—on overall safety, while concurrently evaluating the benefits of technological advancements in IoT-based remote supervision.

The analysis employs a centralized control unit to assess how sensor-driven data interpretation influences the accuracy of medication delivery. Prototypes of the monitoring model indicate that the integration of NodeMCU with load cells and HX711 amplifiers leads to a significant increase in the early detection of irregularities, such as obstructions or low fluid levels. The system is designed to enhance nursing workflow efficiency by utilizing the Blynk IoT platform to provide continuous updates and

instant alerts directly to healthcare professionals' mobile devices. While the automation of flow rate calculations significantly affects the precision of prescribed treatments, the inclusion of buzzer alarms and LED indicators at nurse stations contributes the most to reducing medication errors and preventing complications. Adjustments in remote monitoring accessibility can either amplify or diminish the impact of healthcare interventions, ultimately demonstrating the transformative potential of smart infusion systems in clinical settings[2].

Modern clinical practices emphasize the integration of technology to address the critical demands of continuous patient monitoring. This study, conducted by Kabir et al. [2], evaluates an automated safety system designed to mitigate life-threatening risks, such as blood backflow and air embolism. The research considers the impact of human factors—including healthcare personnel fatigue and nocturnal monitoring challenges—on safety, while concurrently evaluating the benefits of automated flow-blocking mechanisms.

The analysis employs a weight-based detection architecture to assess how real-time monitoring influences the prevention of fluid depletion. Prototypes indicate that integrating load cells with a GSM module significantly increases alert reliability compared to manual observation. The system is engineered to enhance response times through a specialized switching valve that terminates flow once the fluid reaches a critical minimum. While the GSM notification system improves the speed of medical intervention, the reverse flow blocking mechanism contributes the most to ensuring patient safety during unattended fluid depletion. Adjustments in sensor sensitivity can either amplify or diminish the impact of the protective system, demonstrating the essential role of hardware solutions in modernizing intravenous protocols. [3]

Modern clinical environments increasingly seek to transition from traditional manual intravenous (IV) fluid administration to intelligent systems to address the lack of remote monitoring and control capabilities. This study, conducted by Rosdi [4], evaluates the effectiveness of an automated infusion pump system designed to track drop counts and detect potential hazards such as tube blockages. The research considers the impacts of human error in manual counting—which can lead to inconsistent flow rates—on patient safety, while concurrently evaluating the benefits of technological advancements in optical sensing and wireless data transmission.

The analysis employs an Arduino-based microcontroller architecture to assess how real-time optical feedback influences the accuracy of flow rate monitoring (measured in drops per minute). Prototypes of the developed system indicate that the integration of low-power laser diodes and optical sensors leads to a significant increase in the reliability of detecting empty bottles and line interruptions. The system is engineered to enhance nursing efficiency by utilizing the Blynk mobile application to transmit live data and status notifications directly to users' smartphones. While the automated counting method shows no statistical difference in accuracy compared to manual counting, the inclusion of remote alert features contributes the most to preventing complications related to unattended IV drips. Adjustments in sensor calibration can either amplify or diminish the impact of the monitoring task, ultimately demonstrating the value of IoT-enabled prototypes in enhancing consistency within clinical settings. [4]

Modern clinical practices emphasize the transition toward retrofittable medical devices that provide precision care without requiring a complete overhaul of existing hospital infrastructure. This study, conducted by Arfan et al. [5], evaluates the effectiveness of an IoT-based monitoring and control platform designed to fit onto standard intravenous (IV) setups. The

research considers the impacts of manual estimation—whereby clinicians rely on personal experience to set drip rates—on the frequency of human error, while concurrently evaluating the benefits of technological advancements in optical drop detection and remote actuation.

The analysis employs a multi-unit architecture to assess how real-time infrared (IR) sensing influences the accuracy of flow rate management. Prototypes of the developed device indicate that the integration of an IR sensor for optical drop detection paired with a specialized actuator unit leads to a significant increase in the ability to regulate infusion rates wirelessly. The system is engineered to enhance clinical portability by utilizing a 3D-printed, electrically isolated housing that ensures the device is independent of the specific fluid or bottle type used. While the automated monitoring of drops per minute significantly affects the consistency of treatment, the implementation of a remote control mechanism contributes the most to preventing complications such as backflow and air embolism. Adjustments in the mechanical clamp positioning can either amplify or diminish the impact of the control unit, ultimately demonstrating the potential of Internet of Medical Things (IoMT) devices to provide high-precision, low-cost care in diverse medical settings. [5]

### 3.Objective

The primary goal of this project is to design a secure, microcontroller-based system that enables authorized control of glucose flow using a solenoid valve, integrated with real-time monitoring of the flow rate and the remaining level in the bottle. The system is built to provide Automation through smart IV flow management and Monitoring via continuous sensor-based supervision of the fluid supply. By supporting both local keypad and IoT-based control, the device ensures the Accuracy of

glucose delivery while restricting access to authorized medical staff to maintain system Security. All critical parameters, including the real-time volume status, are updated on a cloud dashboard for remote supervision, ultimately enhancing patient Safety by preventing infusion risks and errors like empty-bottle complications.

#### 4. Proposed System

The proposed system is a smart, microcontroller-based glucose control solution designed to bring automation, security, and remote monitoring to healthcare administration. At the core of the architecture is an ESP32 microcontroller that regulates the flow of glucose from the IV bottle using an automated solenoid valve. To ensure strict Security, access is restricted through a password authentication mechanism, allowing only authorized medical staff to modify settings. The system supports dual-mode operation, providing a local keypad for on-site adjustments and an IoT interface for remote control via the internet.

Continuous sensor feedback is central to the system's performance: a flow sensor monitors the actual infusion rate to ensure Accuracy, while a level sensor tracks the remaining volume in the bottle. If the fluid level drops below a preset threshold, the system automatically triggers an alert that is uploaded to a cloud-based dashboard for remote supervision. Additionally, an LCD display provides real-time status updates for local monitoring by nurses. By integrating these features, the system significantly enhances patient Safety by preventing clinical risks such as over-infusion, air embolism, or therapy interruptions.

#### 5. Architecture Diagram

The GlucoGuardian is a secure, ESP32-based system designed to automate and monitor intravenous glucose delivery. It uses a solenoid valve for precise flow control, accessible only

through password authentication via a local keypad or remote IoT interface. Integrated flow and level sensors provide real-time data on the infusion rate and the remaining volume in the bottle. This information is displayed on a local LCD and uploaded to a cloud dashboard, where automatic alerts are triggered if the glucose level becomes low. By replacing manual clamps with automated supervision, the system ensures accurate dosage and enhances patient safety.

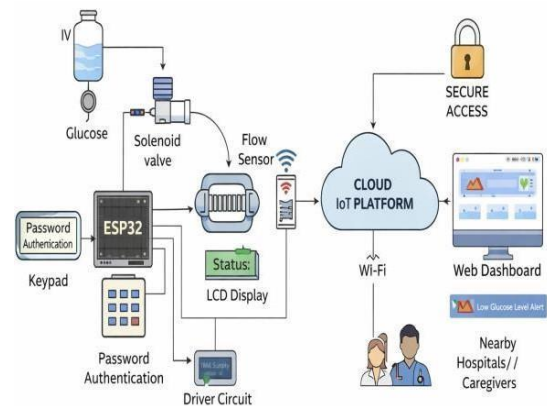


Figure 5.1 Architecture Diagram

#### 6. Algorithm

Based on the system requirements and modules described in your presentation, the project follows a logical control algorithm to manage the intravenous therapy. The process begins with a Security and Authentication phase, where the system executes a password-validation loop to ensure that only authorized medical staff can access the controls. Once the user is authenticated via the local keypad or IoT interface, the Control and Infusion phase starts, where the ESP32 microcontroller processes the input to actuate the solenoid valve through a driver circuit, ensuring accurate glucose delivery. Simultaneously, the system enters a continuous Monitoring and Feedback loop, where it samples data from the flow sensor and the level sensor to verify the actual infusion rate against the intended dosage. Finally, the Alert and Synchronization logic performs a conditional check; if the glucose drops below a

preset threshold, the system triggers an immediate interrupt to display an alert on the local LCD and upload the critical data to the cloud dashboard for remote supervision.

## 7. Implementation

### 7.1 Authentication & interface module

This module establishes the security layer and the primary interaction point for medical staff. It involves interfacing a 4x4 Keypad with the ESP32 to implement a password-validation system. Only after successful authentication is the system unlocked for operation. Additionally, a 16x2 LCD display is integrated to provide local, real-time feedback, showing system readiness, authentication status, and current flow data.

### 7.2 Microcontroller Control Module

This is the core execution unit of the project. Using Embedded C in the Arduino IDE, the ESP32 is programmed to act as the central controller. It interfaces with an L293D Driver Circuit, which acts as a bridge to provide sufficient power to the Solenoid Valve. This module translates user commands or automated logic into physical actions—opening, closing, or pulsing the valve to regulate the glucose flow from the IV bottle.

### 7.3 Display & Alert Module

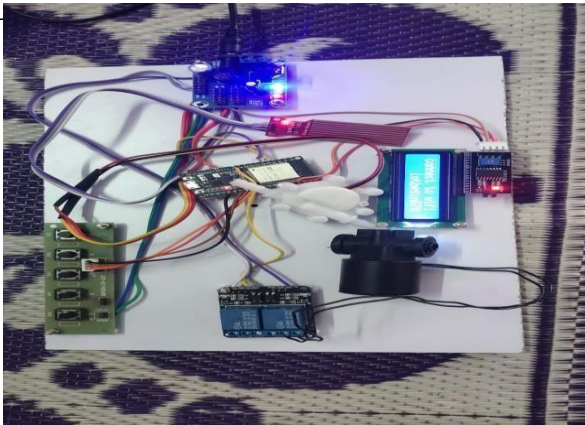
This module is responsible for data acquisition and system safety. It involves the integration of two critical sensors: a Flow Sensor, which monitors the actual drip rate to ensure it matches the required dosage, and a Level Sensor, which tracks the remaining volume of glucose in the bottle. This feedback loop allows the system to detect irregularities and ensures that the physical state of the infusion is always accurately reported to the controller.

## 7.4 IoT & Cloud Monitoring Module

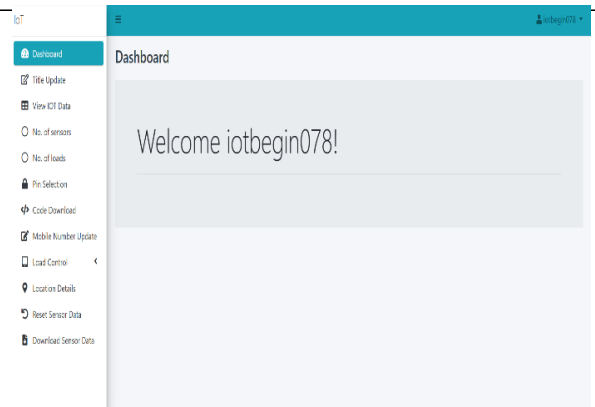
The final module focuses on remote connectivity and data visualization. By utilizing the ESP32's Wi-Fi capabilities, the system connects to a Cloud IoT Platform. Sensor data is transmitted in real-time to a Web Dashboard, allowing doctors to monitor the patient remotely. This module also includes the Alert System logic, which triggers an immediate notification on the dashboard if the level sensor detects that the glucose bottle is nearly empty.

## 8. Experimental Results

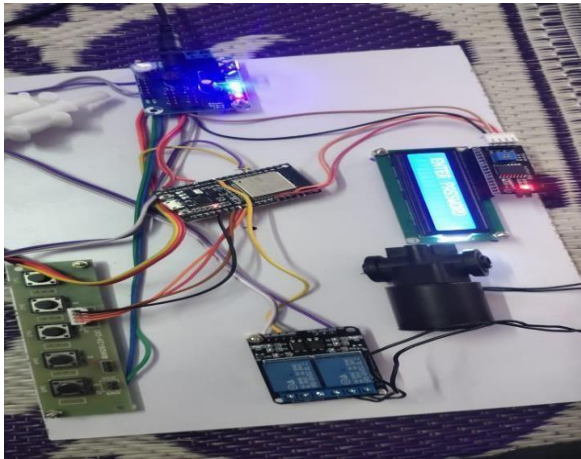
The experimental results of the GlucoGuardian system demonstrate the successful integration of automated control and remote monitoring for intravenous therapy. The testing phase confirmed that the Password Authentication mechanism effectively restricted access to the keypad, allowing only authorized staff to initiate or modify the glucose flow. Once authenticated, the ESP32 microcontroller successfully regulated the solenoid valve through the driver circuit to manage the infusion. Data accuracy was verified by the flow sensor, which monitored the drip rate in real-time, while the level sensor consistently tracked the remaining volume in the IV bottle. These parameters were seamlessly transmitted via Wi-Fi to the Cloud IoT Platform, enabling the Web Dashboard to display the patient's status for remote supervision. Critically, when the glucose level dropped below the predefined threshold, the system automatically triggered a Low Glucose Level Alert, demonstrating the system's ability to prevent risks such as empty-bottle complications and improve overall patient safety in an ICU environment.



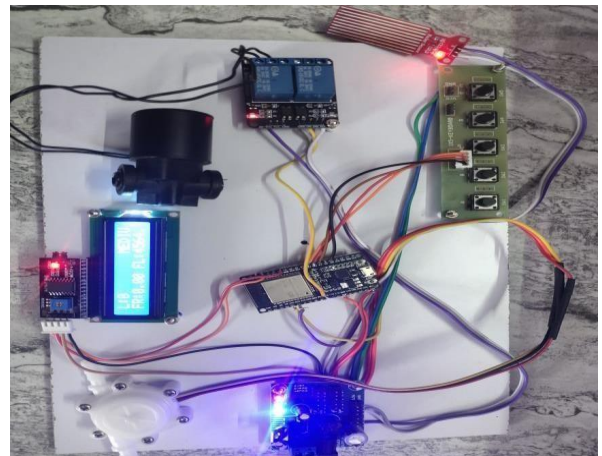
**Figure 8.1 Automated Glucose monitoring System**



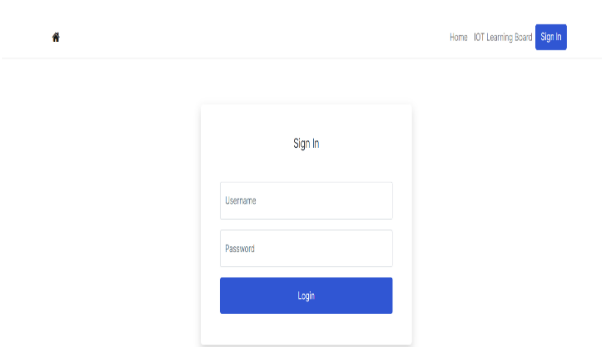
**Figure 8.4 Iot Dashboard**



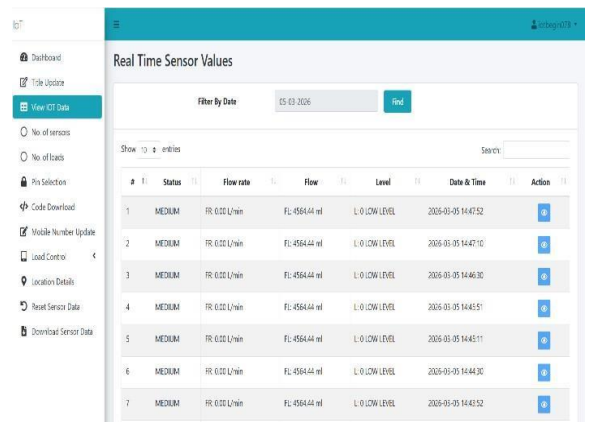
**Figure 8.2 Authentication and userinterface**



**Figure 8.5 monitoring the glucose flow and level values**



**Figure 8.3 Iot Loginpage**



**Figure 8.6 glucose flow and level values**

## 9. Conclusion & Future work

The GlucoGuardian project successfully establishes a secure and automated framework for intravenous therapy, addressing the critical need for constant supervision in ICU environments. By integrating an ESP32 microcontroller with a solenoid valve, the system effectively transitions manual IV management into an automated process that ensures dosage accuracy and minimizes human error. The implementation of password authentication provides a necessary security layer, restricting control to authorized medical personnel only. Furthermore, the continuous monitoring of flow rates and fluid levels, coupled with real-time IoT-based alerts, provides a fail-safe mechanism against complications such as air embolisms and empty-bottle incidents. Ultimately, this system demonstrates how the Internet of Things (IoT) can transform clinical practices by improving nursing efficiency and significantly enhancing patient safety during glucose administration. Looking forward, the system offers several avenues for expansion, such as incorporating Machine Learning algorithms to predict bottle depletion times more accurately and utilizing Blockchain technology to create an immutable log of all infusion adjustments for enhanced data integrity. Additionally, scaling the system into a multi-patient centralized hub would allow a single nursing station to monitor an entire ward, while integrating wearable health monitors could allow the system to automatically adjust flow rates based on a patient's immediate physiological responses, such as heart rate or oxygen saturation levels.

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