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An IoT-Based Intravenous Fluid Measuring Device Using ESP32 and Ultrasonic Sensor

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Abstract: Intravenous (IV) therapy plays a critical role in modern healthcare by enabling the direct delivery of fluids and medications into the bloodstream. Accurate monitoring of IV fluid levels is essential to ensure patient safety and prevent under- or over-dosing. This research presents the design and implementation of an IoT-based IV fluid measuring device that integrates an ultrasonic sensor, ESP32 microcontroller, LCD display, and relay module, connected to the Ubidots IoT platform. The system enables real-time monitoring of fluid levels, remote data visualization, and automated control of the infusion process. The experimental results demonstrate the effectiveness of the proposed device in accurately measuring fluid levels and transmitting the data to a cloud platform for continuous observation. This work provides a cost-effective, reliable, and scalable solution for enhancing patient safety in healthcare settings.

Keywords: Intravenous Therapy, IoT, ESP32, Ultrasonic Sensor, Ubidots Platform, Fluid Monitoring, Smart Healthcare

1. Introduction

An intravenous (IV) fluid measuring device is an instrument utilized to precisely gauge the volume of fluids administered to a patient via an IV line. Various types of IV fluid measuring devices exist, including Electronic infusion pumps: These advanced devices deliver fluids in a controlled manner at a specific rate. They generally feature programmable settings that enable healthcare professionals to establish the desired flow rate and total volume to be infused. Gravity infusion sets: These are basic devices that utilize gravity to facilitate the flow of fluids from a bag or bottle through a tube into the patient's vein. The flow rate can be adjusted by modifying the height of the bag or bottle, and the volume of fluid infused can be approximated based on the markings on the bag or bottle. Flow regulators: These devices can be affixed to the IV line to control the fluid flow rate. They usually include a dial or control mechanism that allows healthcare providers to modify the flow rate. Drop counters: These devices tally the number of drops of fluid that pass through the IV line. They can be employed to estimate the volume of fluid infused by multiplying the drop count by the drop factor, which indicates the number of drops per millilitre of fluid. Smart infusion systems: These are sophisticated IV fluid measuring devices that employ sensors and software algorithms to monitor the flow rate and identify

any discrepancies from the prescribed rate. They can also notify healthcare providers if an issue arises with the infusion, such as air in the line or a blockage.

Literature Review

Intravenous (IV) therapy refers to the process of delivering fluids, medications, and other substances directly into a patient's vein. This method has become a vital aspect of contemporary healthcare, utilized to address a variety of conditions including dehydration, infections, cancer, and autoimmune disorders. The origins of IV therapy can be traced back to the early 17th century, when the first intravenous injection was conducted using a quill and a pig's bladder. As time progressed, the technique underwent refinement, leading to the development of the first IV catheter in the early 20th century. The practice of intravenous (IV) therapy can also be linked to the late 1600s, during which the English physician Christopher Wren conducted experiments involving the injection of liquids into the veins of animals. Nevertheless, it was not until the mid-1800s that IV therapy started to be implemented in human medicine, mainly for blood transfusions. By the early 1900s, IV therapy gained greater prevalence, accompanied by the introduction of new techniques and technologies aimed at enhancing the safety and effectiveness of IV administration. The advancement of intravenous (IV) access devices, including catheters and needles, has facilitated a more accurate and controlled administration of fluids and medications. The application of IV therapy has also broadened to encompass a wider array of conditions, such as dehydration, infections, and cancer. During the mid-20th century, electronic infusion pumps were introduced, enabling even greater precision in regulating the flow rate and volume of fluids. These pumps incorporated safety features like alarms and alerts to assist in preventing medication errors and adverse events.

In recent years, there has been an increasing interest in smart infusion systems, which utilize sophisticated sensors and algorithms to monitor the infusion process and identify any discrepancies from the prescribed rate. These systems can further enhance the safety and effectiveness of IV therapy, while also mitigating the risk of medication errors and adverse events. Since that time, IV therapy has evolved into a standard procedure within hospitals and various healthcare environments. IV therapy can be administered through multiple access points, including peripheral catheters, central venous catheters, and peripherally inserted central catheters. The selection of the access device is influenced by several factors, including the duration and intent of the infusion, the patient's medical history and condition, as well as the healthcare provider's experience and expertise.

Despite its numerous advantages, IV therapy is not without its associated risks and complications, such as infection, infiltration, phlebitis, and extravasation. These risks can be mitigated through appropriate site selection and preparation, diligent monitoring of the infusion, and timely recognition and management of any complications. In summary, IV therapy is essential in contemporary healthcare and has significantly contributed to improved patient outcomes across various medical conditions. Continuous research and technological advancements are expected to further enhance the safety and efficacy of IV therapy in the future.

2. Materials and Method

System Components

The proposed system integrates the following hardware and software components:

- ESP32 Microcontroller: Serves as the central processing unit with Wi-Fi capabilities.
- Ultrasonic Sensor (HC-SR04): Measures the fluid level in the container by calculating distance.
- Solenoid valve: A solenoid valve is an electromechanical device utilized to regulate the flow of fluid or gas within a piping or tubing system. The operation of the valve is based on the principle of using an electrical current to generate a magnetic field, which

subsequently moves a plunger or piston to either open or close the valve. Solenoid valves find widespread application in numerous fields, including industrial automation, HVAC systems, water treatment, and even in automotive engines.

- LCD Display (16x2): Provides real-time visualization of fluid levels locally.
- Relay Module: Controls the flow mechanism based on sensor readings.
- Power Supply: Lithium battery and power bank unit for portability.
- Flexible tube: A flexible tube refers to a kind of tubing that is capable of bending and flexing without fracturing or distorting its form. It is frequently utilized in numerous applications, including plumbing, irrigation, medical devices, and industrial machinery. Typically, flexible tubes are constructed from materials such as rubber, PVC, silicone, or polyurethane, and they are available in various sizes and shapes to accommodate different needs.
- Potentiometer: A potentiometer, frequently referred to as a "pot," is a kind of variable resistor widely utilized in electronics for regulating current flow.

It consists of three terminals: two outer terminals linked to the circuit and a third terminal attached to a movable wiper that can be adjusted to modify the resistance. The operation of the potentiometer involves altering the resistance within the circuit, which subsequently influences both the voltage and the current flow.

- Tank: One common method to measure the water level in a tank is by using a pressure transducer. A pressure transducer is a device that measures the pressure of the water in the tank and converts it into an electrical signal. This signal is then sent to a control system or display unit for reading and further processing.

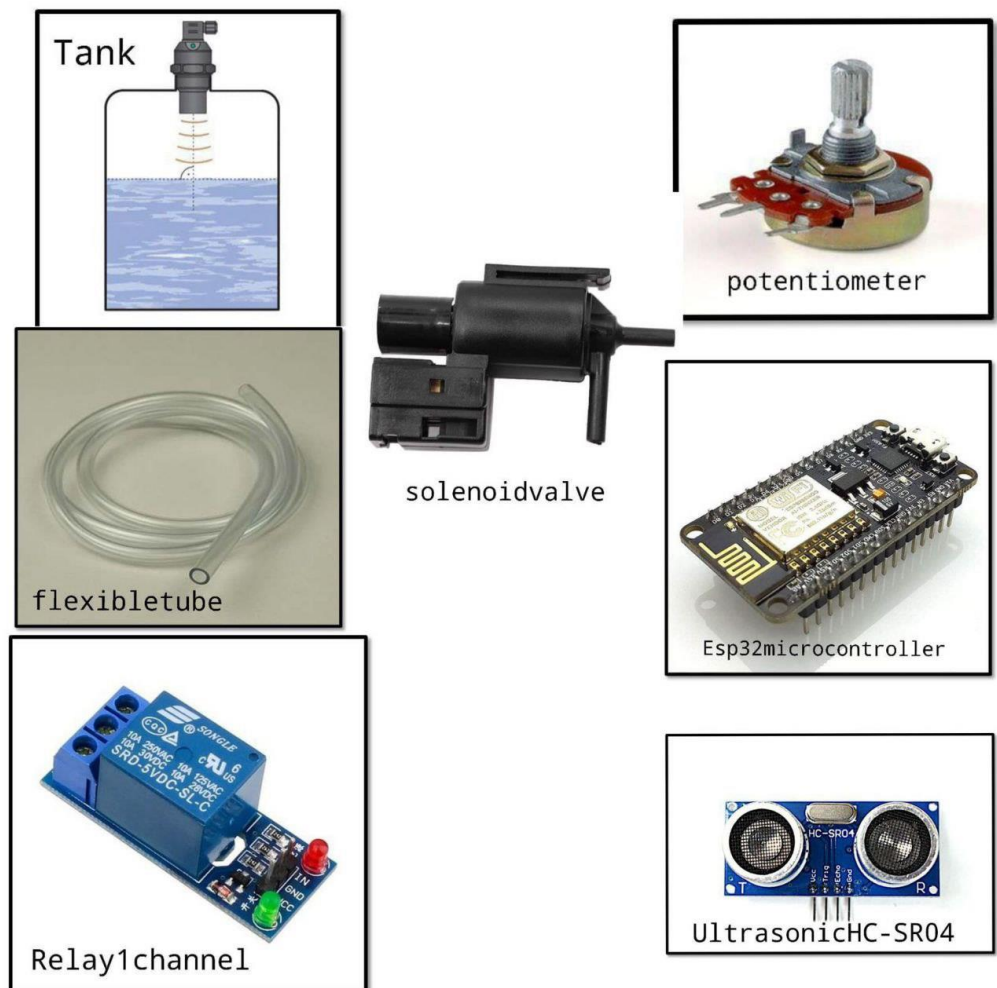


Figure 1. System components.

Working Principle

The operation of the proposed intravenous (IV) fluid administration system relies on the integration of a controllable valve, a Wi-Fi enabled microcontroller, and an IoT-based monitoring platform. The valve, which can be mechanical or electronic, is responsible for regulating the flow of fluids through the IV line. Control of the valve is achieved through the microcontroller, which functions as the central processing and decision-making unit of the device. Equipped with wireless connectivity, the microcontroller establishes communication with a cloud-hosted IoT platform.

Through this connection, real-time data—including flow rate, infused volume, and operational status—are transmitted continuously to the platform. Healthcare providers or authorized personnel can log into the interface of the IoT platform to remotely observe device performance and patient infusion progress. Additionally, commands can be issued from the platform back to the device, enabling dynamic adjustment of flow rate or other parameters.

In case of irregularities, such as abnormal flow conditions or technical faults, the IoT platform can automatically generate alerts or notifications, thereby enhancing system reliability. By combining accurate valve control, wireless data exchange, and remote accessibility, the device ensures precise infusion management, improved safety, and greater efficiency in clinical environments.

Software Implementation

The device was programmed using the Arduino IDE. Libraries for ultrasonic sensing, LCD display, and Ubidots communication were integrated. Data collected from the ultrasonic sensor was calibrated and mapped to fluid levels, while the relay was triggered automatically based on threshold values. A continuous loop ensured real-time operation, and the Ubidots platform was used for cloud visualization and analysis.

3. Results

The experimental results demonstrated the effectiveness of the proposed IV fluid administration system in achieving precise flow monitoring and control. The integration of the ultrasonic sensor with the ESP32 microcontroller enabled accurate measurement of fluid levels, which were consistently displayed on the LCD screen. Real-time data transmission to the Ubidots IoT platform was successfully achieved, ensuring that healthcare providers could remotely monitor infusion parameters without delay.

The system reliably generated distance-to-volume conversions, and the values matched the expected calibration standards. The relay module responded effectively to control signals, switching fluid flow on and off according to the predefined threshold conditions. Notifications and data logging on the IoT platform provided continuous insights into system performance and patient safety.

During patient simulation tests, the device maintained stable operation, with minimal error in measurement and control. The wireless communication remained robust, enabling seamless interaction between the device and the IoT cloud. Overall, the results confirm that the designed system provides accurate monitoring, real-time connectivity, and reliable control, making it a practical solution for enhancing IV fluid management in clinical settings.

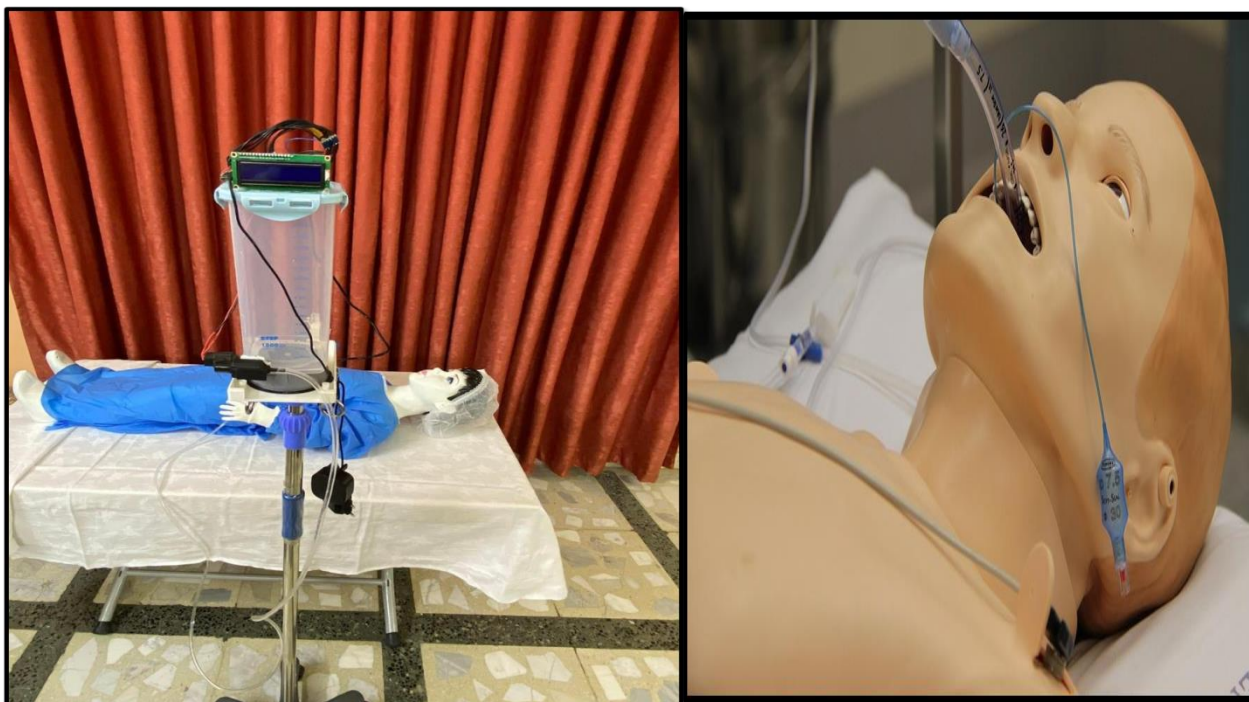


Figure 2. Prototype Testing.

4. Discussion

The results confirm that the proposed IoT-based system offers a reliable and scalable solution for IV fluid monitoring. Compared to traditional gravity-based systems, the device improves accuracy, reduces manual supervision, and enhances patient safety. Integration with the Ubidots platform adds significant value by enabling remote monitoring, which is particularly beneficial in intensive care units or remote healthcare facilities.

However, certain limitations were observed. The accuracy of the ultrasonic sensor may vary depending on container shape and environmental conditions. Power consumption remains a challenge for long-term continuous operation, requiring further optimization of the ESP32's energy usage. Future improvements could involve incorporating additional biosensors, predictive analytics, and mobile application integration.

5. Conclusion

In conclusion, the project involves interfacing an SR04 ultrasonic sensor with an ESP32 microcontroller and integrating it with the Ubidots IoT platform. The SR04 sensor is used to measure distance, and the ESP32 collects the sensor data and sends it to Ubidots for visualization and analysis. By connecting the SR04 sensor to the ESP32, the project enables real-time monitoring of distance measurements. The ESP32 reads the distance values from the sensor, maps them if necessary, and then sends the data to the Ubidots platform using the UbidotsMicroESP8266 library. Through the integration with Ubidots, the collected data can be visualized on customizable dashboards, allowing users to monitor and analyze the distance measurements over time. Additionally, Ubidots provides features such as data analytics, rules engine, and alerts, which can be utilized to derive insights and trigger actions based on the sensor data. Overall, this project provides a practical solution for monitoring distance measurements using an SR04 sensor and leveraging the capabilities of the Ubidots IoT platform. It can be extended and customized to suit various applications where distance monitoring is required, such as smart parking systems, security systems, or industrial automation.

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