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Advanced Saline Infusion Management System With Real-Time Monitoring and Automated Flow Regulation using IoT

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Abstract: *The present arrangement, constant supervision by a nurse or caretaker is required to avoid the saline bottle level from not being monitored regularly. The flow of intravenous fluid is regulated using a roller clamp system. If the nurse or caretaker does not check the emptying of the saline bottle in due time, it can result in the hazardous situation of blood reverse flow from the patient to the bottle, calling for instant control in emergency conditions. Our system uses three sensors located externally near the saline bottle to detect liquid levels. The first sensor shows when the saline bottle is full, the second when half of the saline has been infused, and the third, indicating low saline level, triggers an actuator to close the flow. This is followed by an instant alert to the nurse, and the concerned data is also sent to the dashboard for complete monitoring. In addition, the system incorporates inputting medicine information into a database, and the actual status of the saline is displayed prominently on the graphical user interface (GUI) dashboard. The use of a microcontroller makes it easier for communication between the database and the whole system. Moreover, a servo motor is utilized to stop the flow of saline automatically when it reaches the last level, improving the safety features. To offer timely alerts, a buzzer is sounded, providing timely alertness to situations of prime importance*

Keywords: Non Contact Liquid Level Sensor, Interactive Dashboard, Emergency Alert Indication, Automatic Flow Control, IV-Intravenous Fluid

I. INTRODUCTION

The Smart Saline Level Monitoring System will automatically track the IV(Intravenous Fluid),
reducing the need for constant manual monitoring by healthcare professionals[1]. The system utilizes sensors to track saline levels and gives real-time notification when the fluid is at emergency levels[2]. To avoid emergency situations such as of blood back flow, bulge in veins, an actuator stops the flow automatically when the saline runs out. The system has a remote monitoring graphical user interface (GUI) dashboard as well, through which nurses and physicians can monitor the IV status of the patient effectively. It enhances patient safety and streamlines hospital workflow efficiency by incorporating automation and real-time notifications.

1.1 NON-CONTACT LIQUID LEVEL SENSOR

In hospitals, real-time monitoring of IV (Intravenous Fluid) saline is necessary to avoid complications, but manual supervision is time consuming and also it is liable to error. Our system offers a smart solution which has non-contact liquid level sensor to measures liquid levels with accuracy and without touching the liquid to preserve hygiene, accuracy, and real-time measurement through ultrasonic, capacitive, or optical sensing technology. In our Smart Saline Level Monitoring System, like this sensor constantly monitors the saline level in an IV (Intravenous Fluid) bottle and detects whether it's full, half-full, or low, and refreshes GUI-based dashboard with real-time saline levels, name of medicine, and prescribed dosage for easy monitoring. When the saline is in emergency level, the system will automatically halt the flow to avoid from back flow of blood, budge in veins and also alert the nurse for timely action[4]. A microcontroller provides an easy interface to the sensor, database, and dashboard to make it run smoothly. By automating the monitoring of saline levels, this system increases patient safety,reduces labor for hospital personnel, and optimizes efficiency in IV fluid management.

1.2 INTERACTTIVE DASHBOARD

The interactive dashboard is a live visual interface used to monitor and manage the saline levels in our Smart Saline Level Monitoring System easily. It displays saline levels (full, half-empty, low), medicine details, dosage, prescribed time period, patient name, patient ID, disease, prescribed medicine, flow rate, and the status of the saline (normal or emergency) in an easily comprehensible manner. When the saline level is low, the dashboard automatically switches from the normal to emergency for that particular patient and generates an alert notification to the nurse, so that the nurse can intervene in time. Combined with a microcontroller, it provides smooth communication between the sensor, database, and monitoring system, enabling real-time visualization of data, system alerts, and automatic flow controls. By reducing the exertion of manual monitoring, the interactive dashboard makes hospitals more efficient, patients safer, and IV fluid infusions more streamlined[2].

1.3 EMERGENCY ALERT INDICATION

Emergency conditions in hospitals demand prompt actions to avoid complications. Conventional saline delivery is subject to manual inspection, which can lead to delay, backflow of blood. Our system solves these problems by streamlining the monitoring and alert process and automating it. When the level of saline drops to a critical point, the system shuts off the flow and sends an immediate alert to the nurse or caregiver[4]. The alert is then shown on the GUI dashboard such that medical experts can respond with urgency. It is especially very important for patients in ICU departments, where action should be immediate to save life. By introducing an intelligent emergency response mechanism, our system avoids manual errors immensely, improves the safety of the patient, and ensures smooth hospital workflow.

1.4 AUTOMATIC FLOW CONTROL

Our Smart Saline Level Monitoring System is pre-installed with an auto flow control system for secure and effective IV (Intravenous Fluid) infusion[5]. The system tracks the saline constantly in three levels—full, half, and low. When the low level is reached, the flow of saline gets stop automatically through an actuator attached in the IV(Intravenous Fluid) tube, through that we can prevent from backflow of blood, budge in veins, and reduced need for adjustment manually. It features a built-in GUI dashboard for real-time remote monitoring with alert messaging to healthcare personnel. Automation delivers maximum patient protection, minimizes human error, and streamlines hospital workflow for maximum efficiency.

II. LITERATURE REVIEW

P. Pearline Sheeba et. al., [1] (2016) stated that Saline Infusion Level Detection and Heart Rate Monitoring System is a proposal towards improved patient care at hospitals. The system integrates the detection of the saline level along with heart rate monitoring to reduce human errors and maintain patient safety. The study highlights the importance of an automatic system which can check the saline level and the patient's vital signs continuously. However, the system is still reliant on human action to modulate flow, which can limit its capacity to fully automate saline infusion. The study points out that the role of continuous monitoring, which is automated and has the capability to, in addition to alerting medical personnel, also take corrective actions on its own, cannot be overemphasized.

Shyama Yadav and Preet Jain [2] (2016) stated that their research on cost-effective, real-time e-saline monitoring and control system aims to counter the limitations of traditional saline monitoring. With the inclusion of GSM technology, the system can send notification alerts to medical professionals when the saline level reaches a dangerous point. The

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system is helpful in eliminating human oversight errors and facilitating timely intervention. Yet, the lack of an automatic saline flow control system implies that the medical professionals have to intervene manually in changing the saline injection, reflecting the shortcoming of achieving complete automation. This paper forms a starting point for more advancements, such as the implementation of IoT and AI-based automation.

D. Kothandaraman et al., [3] (2019) wrote that the architecture of an efficient multicast routing algorithm for IoT-based healthcare applications is responsible for guaranteed real-time data transmission in patient monitoring systems.The work points out the network reliability and efficiency needed to send critical health data, including saline levels, to remote monitoring sites. This effort is crucial in assisting to relieve data congestion and latency issues for IoT-based healthcare applications. Based on the study, highly optimized networks could provide a profound increase in response times and dependability of automation-assisted medical care monitoring, thereby being a principal element towards formulating wise saline monitoring technologies.

Manoj Kumar Swain et al., [4] (2015) wrote that the Smart Saline Level Indicator cum Controller is a major milestone towards automating saline infusion monitoring. The system will detect automatically the depletion of saline and stop the flow to prevent negative effects such as air embolism. Although the system effectively eliminates the need for continuous human monitoring, it fails to combine real-time data with a centralized monitoring system. According to the study, combining cloud-based monitoring and predictive analytics has the potential to further enhance the efficiancy and user-friendliness of such automated systems in hospitals. The study shows the ability of IoT and AI to enhance the reliability and accuracy of saline monitoring systems.

C. C. Gavimath et al., [5] (2012) believed that the development of an adjustable saline flow rate measuring device with GSM-based remote monitoring facility provides a notable contribution to patient safety.The system of concern is to monitor saline infusion levels and provide warnings for intervention. The work highlights the importance of remote monitoring in easing the workload of medical practitioners and giving timely medical response. Yet, the lack of an automatic mechanism of flow regulation with integration remains a drawback. The integration of machine learning techniques for predictive analysis and automatic flow adjustments may enhance the capability and overall impact on health administration by the system, as indicated in the research.

2.1 EXISTING SYSTEM

The majority of the world's hospitals and healthcare facilities utilize saline infusion systems relying on pre-set pressure valves to regulate the flow of liquid down the tube. The systems remain largely manual, however, in the sense that healthcare providers must monitor them continuously. Saline flow is mechanically regulated, but not real-time monitored or adjusted automatically based on patient needs. When the saline runs out, the system closes the flow and alerts the medical team by making a buzzer sound. This process is while controlled delivery of the saline is offered, yet it remains a manual-intensive process[1].This is not easy in high-pressure hospital settings where the nurses must handle multiple patients at once. The absence of intelligent monitoring and automatic control results in a constant threat of response delay, which may result in complications, particularly in critical care cases. With the world becoming increasingly technological with each passing day, the demand for an efficient and smarter saline monitoring system that can make the process automatic, minimize human intervention, and maximize patient safety is on the rise.

III. PROPOSED SYSTEM

The saline monitoring system is a GUI-based system to enhance IV (Intravenous Fluid) infusion efficiency in hospitals. It provides real-time monitoring by presenting critical information like type of medicine, dosage, and time prescribed on a dashboard linked to a central database. A microcontroller acts as a liaison between the system and the database, which ensures a seamless update. The system works at three levels: at level one, it indicates that the saline bottle is full; at level two, it reports that half of the saline has been utilized; and at level three, it indicates that the saline is running low. After the saline passes this crucial point, the system automatically ceases the flow of fluid to prevent complications and sends a prompt alert message to the nurse to take action promptly[5]. The feature prevents any complications like air embolism, dehydration, or backflow of blood from happening. Once past the last point, the flow is completely cut off to ensure patient safety. By automating the monitoring procedure, this system reduces the load on medical professionals, minimizes human errors, and provides effective patient care with timely interventions. By incorporating IoT technology, it is a viable, cost-effective, and cutting-edge healthcare solution that improves overall hospital management and patient safety.

The components needed for the Smart Saline Level Monitoring System are as follows:

- **ESP32** (Microcontroller for processing)
- **Non-Contact Liquid Level Sensor** (Saline level detection)
- **Buzzer Module** (Emergency alert system)
- **GSM/Wi-Fi Module** (Real-time alerts & communication)
- **24 × 7** (Status & feedback display)
- **Servo Motor** (Automatic flow control)
- **Jumper Wires**
- **USB Cable**

3.1 Data Acquision

The Smart Saline Level Monitoring System begins with saline level measurement using non-contact sensors. The sensors are placed alongside the IV bottle to detect the liquid level without contact. All this is done for reasons of hygiene, accuracy, and minimizing the risk of contamination. The real-time data gathered will be the source of subsequent processing and monitoring.

3.2 Saline Level Monitoring

After the data is obtained, the system also keeps monitoring the saline level and classifies it into three levels: Full (100%), Half (50%), and Emergency (10%). The monitoring system ensures that the flow of saline is controlled, so there are no interruptions or excessive drainage. This classification enables the healthcare staff to monitor IV (Intravenous Fluid) status effectively and take timely intervention when necessary.

3.3 Emergency Alert Mechanism

Once the saline level is at the emergency limit (10%), the system activates an alarm mechanism. This involves providing real-time alerts on the nurse's dashboard and initiating a buzzer alarm to get instant attention. The alert integration guarantees that no saline bottle remains unattended, lowering the possibility of air embolism and potential harm to the patient[1].

3.4Automated Flow Control

To maximize patient safety, the system features an automatic blockage of flow once the saline is at the emergency level[3].It blocks the IV (Intravenous Fluid) from being continued past this level once this level is critically low, thereby closing the window for air entering into the patient's bloodstream. This component automates an important duty that might otherwise have to be performed manually, which increases efficiency and reliability to the medical process.

IV. ALGORITHM DESCRIPTION

4.1 Decision Tree Algorithm

The Smart Saline Level Monitoring System uses a Decision Tree Algorithm to predict and classify saline levels from sensor data. Preprocessed data from non-contact sensors are examined to classify levels into Full (100%), Normal (50%), and Emergency (10%).The model is hierarchical in decision-making, where real-time inputs elicit the right response. At 10% (Emergency), alert, buzzer, and dashboard update provide real-time intervention. With a 70-30 train-test ratio and the Gini Index as the splitting metric, the model performs effective decision boundaries. Positive validation on numerous test cases confirms the system to monitor appropriately in real time and automatically alert, minimizing patient risk and avoiding saline loss.

4.2 Block Diagram of the Proposed System

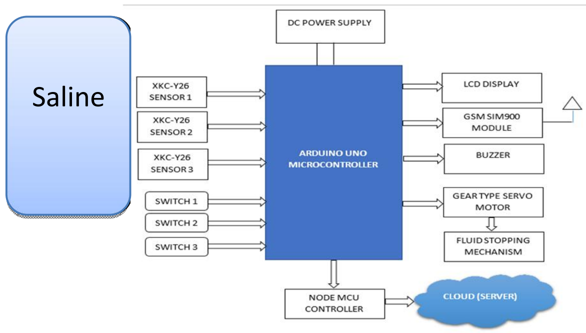

Figure 4.2.1Block Diagram of the Proposed System

Figure 4.2.1 Block Diagram of the Proposed System shows the integration of the sensor, microcontroller, database, dashboard, and alert system for real-time saline monitoring.

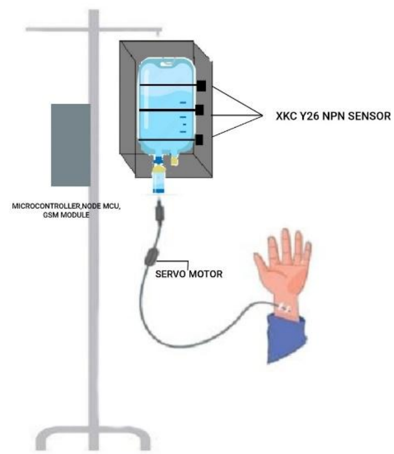

Figure 4.2.23D Diagram of the Proposed System

Figure 4.2.2 3D Diagram of the Proposed System visually represents the Smart Saline Level Monitoring System, showcasing the arrangement of the sensor, IV bottle, microcontroller, display, and alert system in a real-world setup.

V. RESULT ANALYSIS

Smart Saline Level Monitoring System is intended to improve hospital efficiency and patient safety through real-time monitoring of saline levels. Through non-contact sensors, the system automatically tracks saline levels and categorizes them into three phases: 100% (Full), 50% (Moderate), and 10% (Emergency).Upon reaching the emergency level, it automatically triggers a buzzer signal, alerts through GSM, and updates the dashboard to notify healthcare staff.In addition, the system controls automatically to prevent over or under-infusion, reducing the likelihood of complications. Under intensive testing, it has proved to be accurate, consistent, and harmoniously compatible with hospital environments. With automation of the monitoring process, this groundbreaking, non-invasive system reduces the intervention of man to a great extent, the risk of man-induced error, and the general efficacy of saline infusion in hospitals immensely.

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Figure 5.1 Output images

Figure 5.1 illustrates the hardware setup, showcasing the microcontroller, sensors, and communication module for real-time saline monitoring and automated control.

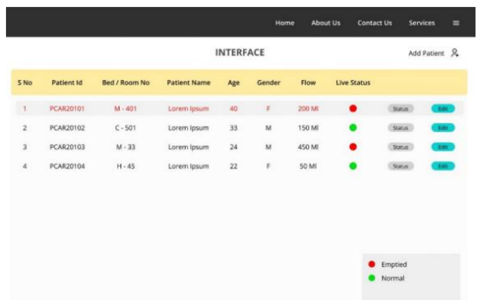

Figure 5.2 Output images

Figure 5.2 displays the real-time saline level status, ensuring accurate monitoring and automated alerts. It provides clear visual indicators and notifications for timely nurse intervention and flow control.

VI. CONCLUSION

The age of technology continues to change, the development of automated health monitoring systems has increased patient care exponentially, offering higher safety and less workload for medical professionals such as doctors, nurses, and caregivers. Our proposed system is designed to function parallel to such technologies by offering real-time monitoring of saline level, providing immediate alert to the medical staff, and possessing an intelligent feature that can automatically stop the saline supply when the need arises. By this revolutionary process, human intervention is brought down to the minimum, any potential medical complication due to excessive administration of saline is eliminated, and overall efficiency in handling the patient is enhanced. With the inclusion of top-end automation and smart monitoring aspects, the system not only renders hospital functioning economical but also achieves a safer and more secure healthcare setup.

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