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Smart Saline Assistance System

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***Abstract*— The traditional Intravenous (IV) system is vulnerable to human error and other risks like backflow of blood, air embolism and various other problems if unattended at a time. This research aims to develop a smart IoT based monitoring and controlling system to administer the saline infusion effectively. The system consists of two systems, namely the patient bedside system and nurse side system. At patient side, flow rate is measured by the IR sensor placed parallelly across the drip chamber, and the volume of saline bottle is calculated using load cell to know when the bottle empties. An actuator mechanism is designed to set the desired flow rate. All critical parameters and alerts are given to the nurse side system with the help of a real time web server page and a portable handheld device enabling online as well as offline communication.**

***Index Terms*— Internet of Things (IOT), Saline Monitoring, Intravenous (IV), Patient monitoring, Nurse assistance.**

I. INTRODUCTION

One of the fastest ways to deliver fluids and medications to the human body is through IV therapy. Saline is a versatile and important tool in the medical field. Its sterile nature, abilityto hydrate and its use in various procedures make it an essential solution in hospitals. Ongoing surveillance of continuous saline level monitoring is a crucial task; if a mistake ismade, the patient may later experience negative effects or issues. It can be detrimental to their health, or it might affect their nerves. Therefore, all hospital staff, including doctors, nurses, and caregivers, are responsible for monitoring the saline level.

Saline is given to a patient whenever they start to feel dehydrated. All hospital staff, including doctors, nurses, and caregivers, are responsible for monitoring the saline level. When medical workers cannot continuously check the saline level, hazardous effects like backflow of blood may occur as shown in Fig.1. It happens just after the saline finishes, blood rushes back to the saline bottle due to the difference in blood pressure and pressure inside the empty saline bottle. It may cause a reverse flow of blood to the saline bottle from their vein which results in loss of blood. The proposed work will try to overcome all the issues faced by the existing system. The detailed discussion of related work in the direction of automation of IV systems is described in the succeeding sections. Also, sometimes when air bubbles from the IV line are not removed then it leads to air embolism which can compromise with the patient's life.

Fig.2 shows the blockage of blood due to much larger size bubbles. Large air bubbles can entirely cause an air embolism if they enter the patient's bloodstream. It restricts the flow of blood via an artery or vein, preventing it from reaching the body's critical organs. Stroke or death become a genuine threat if the air embolism prevents blood flow to the brain.

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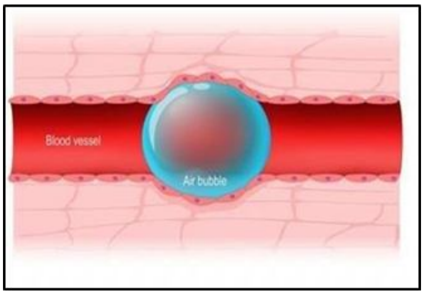

Fig. 1 Backflow of blood (Image Courtesy:[7]) Fig. 2 Blockage due to air bubbles (Image Courtesy:[8])

Currently, there are no contactless and reliable systems available in the market to avoid contamination of saline fluid. Most of the systems specific to saline bottles. The setup of such requirements is a pre-built IV stand. Infusion pumps used in hospitals are very expensive. An accurate and cost-effective system is not available in the market which can measure flow/drip-rate efficiently.

II. RELATED WORK

An automated intravenous blood infusion device that uses a load cell sensor to prevent reflux is discussed [1]. It works on the principle of Wheatstone Meter Bridge. It is an IoT based monitoring and control platform for IV infusion setup that is low-cost, highly dependable, and enables medical personnel to wirelessly monitor and manage the IV infusion setup system. Drop detection is observed using IR sensors, the drip rate is controlled by actuator units, and the entire process is managed and carried out by a microcontroller unit. The proposed model is very trustworthy and advances IV therapy by employing current technology. The MQTT-S protocol has been suggested by the authors in [2] because it is effective for low-cost and low-power devices. Due to its capabilities for asynchronous communication with message buffering, MQTT-S also offers guaranteed delivery of messages. The saline tube's clamping circuit mechanism and the testing of several sensors presented the most challenges for this project. IoT generally offers a new dimension to patient monitoring in the healthcare sector. Therefore, it is guaranteed that this technology would be practical and easy to use in remote hospitals [3]. The problems faced by authors was to determine the saline flow rate with different periods, it was found that the system was able to control the flow rate for a specified time only [4]. The authors in [5] used wireless water level sensor for predicting the saline level and to stop the saline infusion a solenoid valve is used. A 3D printed structure around the drip chamber which embeds IR led in it which is responsible for detecting the drops and depending on the drop count the saline level is predicted. The system comprises of an ESP32 Microcontroller and an IR sensor. The transmitter and receiver of IR are placed in such a way that they detect the drops falling in drip chamber with the help of a 3D printed structure [6].

Problems that are mostly encountered due to gravity based IV sets is that the drip rate, flow rate is controlled manually by the nurses for each patient which is time-consuming and a cumbersome task. Also, if air bubbles are not removed properly from the IV then it may lead to a condition of air embolism. There is also a serious problem with Reverse blood flow. Bending of the pipe due to the patient's hand movement results in the stopping of saline flow due to which infusion time increases. A Roller clamp in the IV set is used to control the flow rate. Sometimes due to a defective IV set, the roller clamp malfunctions through which flow rate increases or decreases, and the time of infusion also varies. The proposed system aims to overcome all the difficulties faced by previous systems and improvise the system by adding additional features which will reduce the workload of caretakers. A cost-efficient system without human intervention is proposed.

III. PROPOSED SYSTEM

The system comprises of two units firstly at the patient bedside called as the Patient Monitoring system and another at the nurse side called as Nurse Assistance system communicating with each other as depicted in Fig.3.

Patient Monitoring System

The system on the patient's bedside consists of all the monitoring circuitry as shown in Fig. 4 and Fig. 5. The saline bottle is hung over the load cell to determine its weight which can further determine the quantity of fluid left inside the bottle. Also, using two Infrared Photodiodes placed parallel across the drip chamber, drop rate can be calculated. The collected data from the sensor is fed to the microcontroller and displayed at the OLED screen on the patient monitoring system. As per the data obtained from the sensor, an actuator mechanism is used to maintain the desired flow rate and automatically squeeze the IV tube before the saline bottle gets emptied. Using an inbuilt Wi-Fi module inside the microcontroller that can send all the data to the cloud and the smartphone as well. Further, for offline communication transceiver is used which will send the alert information to the nurse station monitoring system.

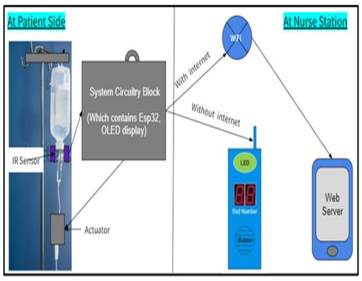

Fig. 3 Communication from Patient side to Nurse assistance system

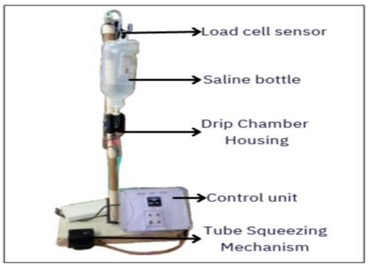

Fig. 4 Saline Monitoring system

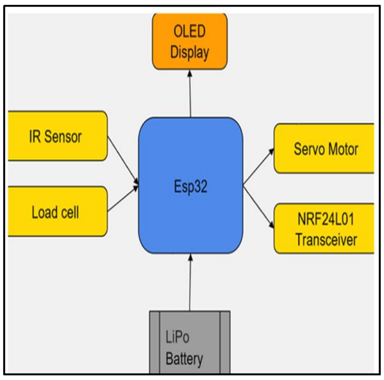

Fig. 5 Hardware implementation for Patient Monitoring System

Nurse Assistance system

All the alerts information from the transceiver can be given to the nurse using a handheld alert device which consists of an OLED display and LED. For offline communication, NRF24L01 Transceiver is used which will send the alert information to the nurse station via a portable handheld alert indicator. Also, with the help of a buzzer fitted the nurse can be alerted about any issues occurring with patients using the IV set as shown in Fig.6.

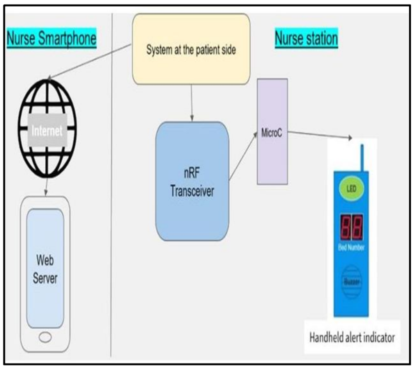

Fig. 6 Nurse Monitoring System

IV. Implementation Methodology

In Patient monitoring system firstly the crucial parameters that are to be displayed are saline level, estimated time to finish the saline, drip rate, flow rate. The system at the patient side is implemented with the help of ESP32 microcontroller which becomes the heart of the system and responsible for all monitoring of all parameters. To monitor saline level a load cell is used which is interfaced with microcontroller using HX711 ADC converter. The

IR sensor is interfaced with the controller using the IR module which gives the actual drop counter. To detect the drop with precision and thereby determine the flow rate IR module is mounted on the IV stand with the help of a specially designed structure

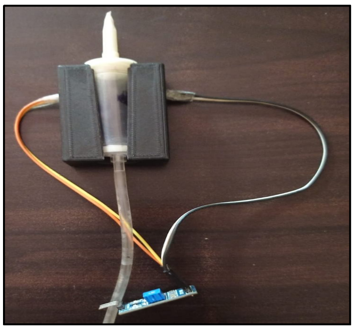

Fig.7 3D printed structure for IR sensor

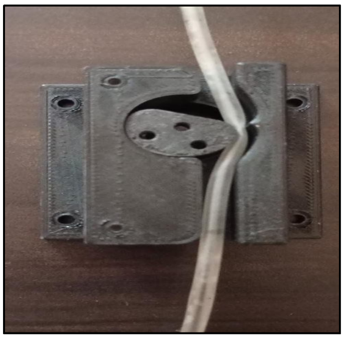

Fig.8 3D Printed Structure for Servo motor

Fig. 7 shows the dedicated structure in which the IR sensor is placed at a fixed position and angle which allows it to count the drops with required precision. The structure for servo motor for proper pinching of pipe is depicted in Fig. 8. The structure is designed to hold and allow proper rotation of the servo, to clamp the pipe properly whenever operated by medical attendee to control or stop flow rate of IV set. The communication between the patient monitoring system and nurse hand-held portable module is established using NRF24L01 transceiver module which allows it to work without internet connection.

The nurse handy module is provided with a display to show the exact bed number of the patient who needs the attention and a LED which will specify the problem with the help of specific color dedicated for specific problem. For e.g. red will indicate the saline bottle is about to finish and need to change it or stop its flow rate, green will indicate the saline flow is stopped due to some other reasons, also, a buzzer to give alert to nurse. This will satisfy the aim of remote monitoring of the designed system and help the nurse to keep track on each patient with convenience.

V. Results And Discussions

The Smart Saline Assistance System is mainly designed to monitor and to some extent control the existing saline IV sets. Another main objective of the system is to alert the medical attendees about the critical conditions. For handling the system and for monitoring the desired parameters the system at the patient side consists of a display. The display consists of user interfaces with the help of which the medical attendees can interact with the system as well as monitor the desired parameters.

Fig.9.User Interfaces for Real time Monitoring at Patient Side

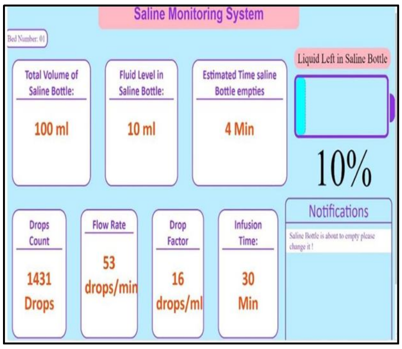

Fig. 10 Initial Values on the Web Server

As shown in Fig.9 the real-time monitored saline level is displayed in the interface at the patient side system. Furthermore, other parameters like drop rate, flow rate, estimated time to finish the saline, etc are also displayed in the OLED display at the patient side which makes it easy to monitor it for the medical workers. A web server is created for giving alerts to nurses with the help of the internet, on PCs or Mobile phones. The web server is created with the help of basic web technologies such as HTML, CSS and JavaScript. The inbuilt Wi-Fi module with the ESP32 microcontroller is used to transmit the desired information on the web server for real time monitoring of parameters. The Ajax library or framework is used for real-time updating of parameters on the web server. This allows the web page to dynamically update the values of all parameters in frequent intervals without manually refreshing the entire page. All the information about crucial parameters can also be viewed on web servers using mobile phones or PCs.

Fig. 10 shows the web server displaying all initial parameters at the start of the saline infusion. For 100ml saline bottle, the threshold selected was 10 percent of the total volume. As soon as the saline level goes below the threshold, an alert is sent to the nurse assistant system. Fig. 11 depicts the web server sending an alert when the saline bottle is about to finish.

Fig. 11 Web server giving alert when saline is about to empty.

VI. CONCLUSION

The proposed IoT based smart saline monitoring and control system for saline is designed and tested. The system is reliable in operation and the intended purpose is well achieved. The frequent requirement of nurse's intervention and caregiver's workloads is drastically reduced via web and mobile apps. Moreover, automatically control and adjustment of saline solution administered to patients is taken care of by the system. The proposed system can also be used offline with the help of a transceiver module in case of interpreted internet service. The feature of the system finds its usefulness in urban as well as rural areas where the scarcity of trained medical professionals always exists.

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