Design and Development of 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 on time. This research aims to develop a 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.**

***Keywords*- Internet of Things(IOT), Saline Monitoring, Transceiver, Intravenous Therapy.**

I. INTRODUCTION

One of the fastest ways to deliver fluids and medications to the human body is through IV therapy. 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 saline, 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. Patients may panic because of the above situation.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 next section.

Fig.1. Backflow of blood

II. LITERATURE SURVEY

To develop any system it is necessary to study the existing research and to thoroughly understand the topic. For that purpose the relevant papers are reviewed and the main context from some of them is discussed.

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 (Internet of Things) based system. The article describes 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].

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.

Currently, there are no contactless systems available in the market to avoid contamination. Systems made are 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.

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

A. Methodology

Entire system comprises two units as shown in Fig.2.First, at the patient bedside also called the Patient Monitoring system and another at the nurse side also called as Nurse Control system. Working of each system is mentioned in below

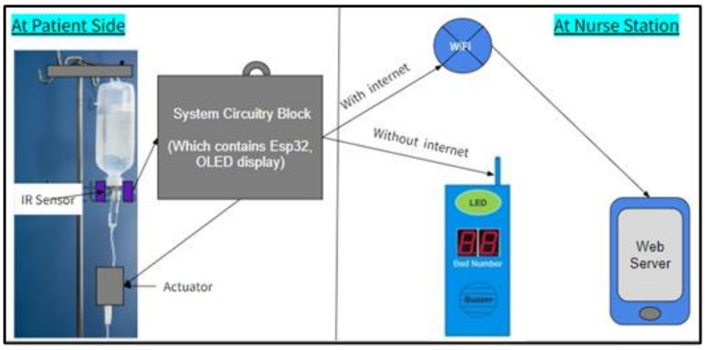

Fig.2. Overview of entire system

1)Patient Monitoring System:

The system on the patient bedside consists of all the monitoring circuitry as shown in Fig 3. The saline bottle is hung over the load cell to determine its weight which can further calculate the quantity of fluid left inside the bottle. Also, using two Infrared Photodiodes placed parallelly 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. buttons can be used to adjust the flow rate as prescribed by the doctor. As per the values obtained from the sensor, an actuator mechanism is used to maintain the desired flow rate and automatically pinch 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 pen-like structure.

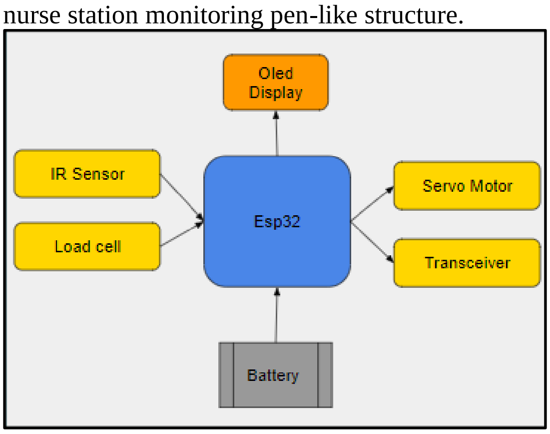

Fig.3. System deployed at patient bed-side

2)Nurse Control System:

All the alerts information from the transceiver can be given to the nurse using a pen-like structure which consists of a OLED display and LED. Also, with the help of a buzzer fitted on a pen -like structure the nurse can be alerted about any issues occurring with patients using the IV set as shown in Fig.4.

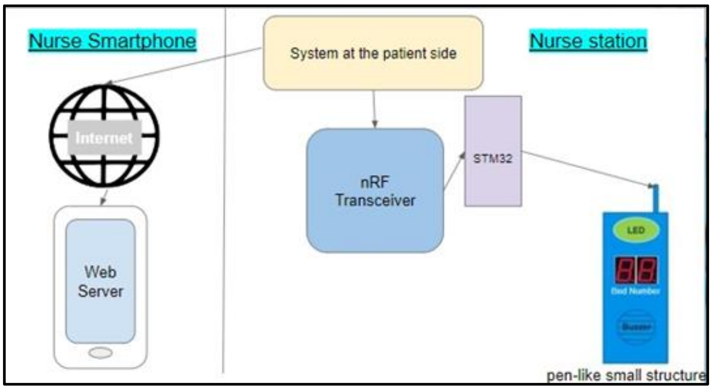

Fig.4. System deployed at Nurse station

B. Algorithm

The algorithm is classic math, to find the unknown by cross multiplying the given value. If 1 drop takes X seconds to drop, then in 1 minute will have 60/X drops.

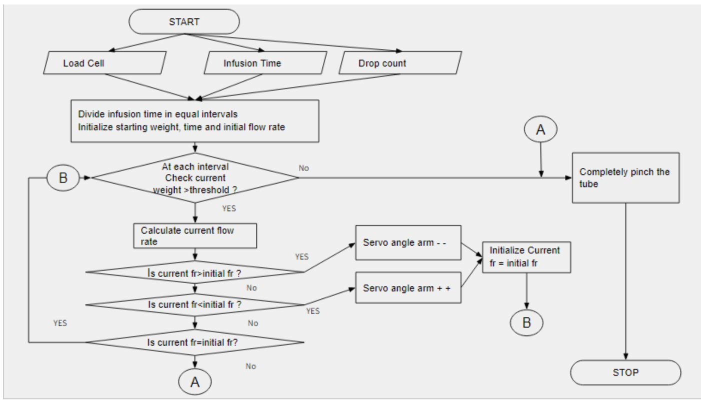

Fig.5. Work flow of the system

The system primarily requires three inputs for its operation that are infusion time as instructed by the doctor, Drop factor of the IV set and volume of saline present in the bag.

Using the above parameter flow rate is calculated using Equation (1) when calculating an infusion by gravity (without an IV pump).

$$Flow\ rate(in\ gtt/min) = \frac{Volume\ to\ be\ infused\ (in\ ml) \times Drop\ factor}{Total\ infusion\ time\ (in\ minute)} \quad (1)$$

Flow rate determines the number of drops falling in unit time.

It is necessary to maintain the flow rate throughout so that infusion gets completed on a given time.

A threshold is set below which the actuator mechanism will stop the saline flow. At every certain time interval, the flow rate is again calculated and if the current flow rate is different from the initial flow rate then the actuator will adjust the saline flow so that it remains constant throughout the infusion.

IV. IMPLEMENTATION

To implement the patient side system firstly the crucial parameters that are to be displayed (Saline level, estimated time to finish the saline, drip rate, flow rate) on the system display are decided. The system at the patient side is implemented with the help of ESP32 microcontroller which becomes the heart of the system at patient side and responsible for all monitoring of decided parameters. For that, 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 good precision and thereby to count them the IR module is mounted on the IV stand with the help of an specially designed structure.

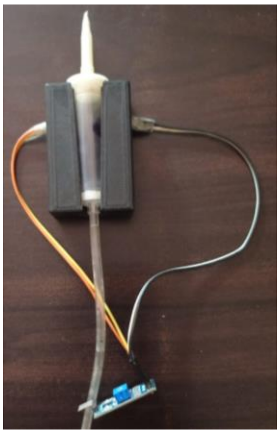

Fig.6. 3D printed structure for IR sensor

Fig.6. shows the dedicated structure in which the IR sensor is placed in at a fixed position and angle which allows it to count the drops with required precision.

Fig.7. 3D Printed Structure for Servo motor

Fig.7. shows the structure for servo motors for proper pinching of pipe. The structure is designed to hold and to 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 side system and nurse handy 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 also an led which will specify the problem with the help of specific color dedicated for specific problem (for ex. red will indicate the saline bottle is about to empty and need to change it or stop it's flow rate, green will indicate the saline flow is stopped due to some other reasons etc) the buzzer is also there in pen sized module 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

It is the interface which helps the medical worker to operate the system. Fig.8.shows the display at the patient side system.

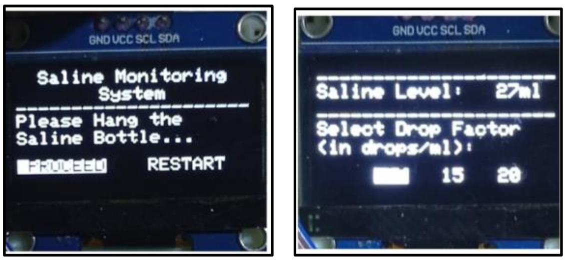

Fig.8.User Interfaces for Real time Monitoring at Patient Side

As shown in Fig.8 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.

IV.CONCLUSIONS

The monitoring and control system for saline that is currently being designed can be utilized as a prototype. System can operate by its stated goals of decreasing nurses or caregivers workloads via web and mobile apps, and it can also automatically control and adjust the amount of saline solution administered to patients. The system can be used offline with the help of a transceiver module. It will be helpful in urban as well as rural areas where the human power is less at an affordable cost.

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