IoT Based Electrolyte level Monitoring System

Vinay Khandagale, Iti Agarwal, Aditya Ujalambkar, Sanjay Ghodake

Abstract: In hospitals, Electrolyte is fed to patients in many ways. One of the important functions is in the form of saline to treat dehydration and thus improve their health. In current health care measures, whenever a saline is fed to any patient, the patient needs to be continuously monitored by a nurse or any caretaker. Monitoring the Saline level in a bottle attached to a patients' body is one of the most important tasks for a Nurse/caretaker. In cases involving ignorance or carelessness, the bottle may get empty and blood can start flowing reverse into the bottle from patients' body. This is a risky situation and needs a better solution. We are developing an IoT based bottle level monitoring system that will detect the saline bottle level at all instances and will send an alert to the hospital's control room in case the bottle reaches it's critical level(30% of initial level) and if there is no response and the level goes beyond 20% on initial level, we stop the flow. We are using ESP8266 Wi-Fi module for processing and communication and load sensor for detecting the bottle weight. The proposed system is not electrolyte specific and can monitor any fluid. A Dc Motor controlled- screw actuated clamp mechanism is used for stopping the flow.

Keywords: IoT, level monitoring, ESP8266 Wi-Fi, electrolyte-specific, DC Motor controlled, notification, screw actuated clamp mechanism

I. INTRODUCTION

Smart Healthcare in India is an essential requirement. With the doctor to patient ratio not meeting global standards, lifting the responsibilities from healthcare workers' shoulders and replacing them with machines will bring a huge positive change in the Health Industry.

Due to unbelievable advancements in technology in recent times, the humans have become totally dependent on the electronic gadgets for reducing their workload to making their life easier in many ways. The health sector, however in our country from many years is dependent on the manual support of doctors and nurses for even pettiest things related to the patient's health. Monitoring patient's electrolyte level is an important task and a necessity for every hospital. Many a times, the electrolyte level is unattended due to the administrative staff's busy schedule and gets below the alerting level. If still not taken care of might even lead to some medical accidents.

Saline/Electrolyte is attached to the patient when the patient's body is deprived of essential nutrients especially in cases of dehydration mostly. A constant manual observation of the saline level in the electrolyte bottle is mandatory.

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If after the saline bottle empties, it is not replaced/removed immediately, then the difference in the pressure between the patients' blood pressure and the empty saline bottle can cause reverse flow of patient's blood into the electrolyte bottle. Our 'Electrolyte Level monitoring system' is an IoT based project that replaces the need of a Nurse/caretaker to constantly keep an eye on the electrolyte bottle level connected to a patient. If the nurse/caretaker ever fails to stop the flow at appropriate time, and the bottle gets empty, the blood flows back into the bottle putting the patient's life in danger. To overcome this problem, we have come up with an IoT based solution that will monitor the bottle level continuously and update it in the control room for alerts at critical level of the electrolyte. If the control room fails to respond, a screw actuated clamp mechanism will stop the flow and save the patient's life.

We calculate the initial weight of the bottle connected with our load sensor and save it in the database. The sensor continuously senses the weight until it reaches to 30% of the initial weight. That is where the critical level of the bottle is. We send an alert to the control room at 30% to change the bottle. If no one responds, and the bottle goes even below to 20% we send an alert again to the control room. We wait for the nurse to respond, after no response, the flow is stopped at 15% of the initial using our DC motor controlled, screw actuated clamp mechanism. The system not only replaces the need of a caretaker but also keeps a database of all the bottles connected to a bed. We have also taken in consideration, the distinguishing of different beds in a hospital with huge number of beds to avoid confusion between systems. The Microcontroller used is ESP8266 which will help in wireless communication and the database is designed in MySQL. The frontend of the system is written in HTML.

II. LITERATURE REVIEW

IOT Based Saline Level Monitoring & Automatic Alert System

In this paper, they have proposed a system for the saline level monitoring and an automatic alert system solution with the help of a rubber band using mechanism in which rubbers along with various other software and hardware are used. The rubber band mechanism helps to easily detect the levels of saline water. LEDs and IR sensors are the main components of the solution. There basically are three levels for detection in which all the three LED lights each associated with one IR sensor glows accurately at each level of the saline bottle. First of all, when the saline bottle is just attached to the patient, the starting level will be completely full so the obstacle (fluid) will pass through the light rays of first IR sensor getting the first LED of the IR sensor to glow. An automatic alert message of partially filled bottle will be sent to the nurse, Similarly when the saline bottle is half filled and nearing to completely empty, the fluid (saline) will pass through the light rays of second

IR sensor and the second LED of the IR sensor will glow and at last when the saline is becoming completely empty, then the same obstacle will pass through the light rays of the third IR sensor and then the third LED of the IR sensor will glow. Then an automatic alert message of completely empty saline bottle will be sent to the doctor. There is even a system provided for stopping the flow of the saline automatically using a micro servo motor. There might be the chances of negligence on the part of concerned authorities towards the patients or maybe they could not attend the patient due to their busy schedule, so in order to avoid the reverse flow of blood from the patient into the bottle after completion of saline transfer from the bottle to the patient, the micro servo motor is used to automatically stop or hinder the interconnection between the bottle and the patient [2].

The system provided and explained is saline bottle dependent and bulky. It interferes with the medical components of the fluid present inside the bottle. The tri-level monitoring is providing extra alertness and ensures triple safety of the patient.

Smart saline level monitoring system using IOT

The paper describes the framework that is composed of different sensors and electrothermal devices. The interconnection is done by means of remote correspondence modules. The system employed Node MCU as the platform for providing network interconnection for communication between the sensors and the doctors and nurses. The sensors' data is important to be transferred from one user end to other in this system which is being facilitated by Node MCU. This system observes the condition of patient from time to time. They used Think Speak application platform for data visualization at every moment. The nurse is needed to access the application to observe all the levels of the saline reached at an instant. They connected resistors and LEDs serially for serial transmission of current on a multiple board. Number of resisters used in the solution are three and each wire separately is used for each resister and one other wire is used for grounding the system. The ground wire is connected to the GND pin of Node MCU while one wire is connected to A0 pin of Node MCU. Then the connection wire of the ground is considered as the base in this system. The system is applicable for transparent liquids (e.g. water, dilute saline) mostly. The saline is marked at three levels for three different LEDs to glow. When the level of water reaches to the marked point one of the bottles, the first LED may glow. The process continues and the procedure is repeated for the rest of the marks on the bottle until the saline bottle is empty.

The Wi-Fi module present in Node-MCU is being used to store all the data including temperature and current level related information of the saline bottle connected. The user needs to press the refresh or restart button present on the module each time a value related is displayed so that fresh values can be displayed. No separate display is used.

The room temperature is even measured using LM35 to ensure the patient's living conditions. The paper even depicted the use of a TILT sensor along with the system to observe the motion of patient's body. It is advised to use this sensor in case of any serious health condition of the patient to measure and observe its condition. There may be a provision of sending a notification of patient's body movement with its help.[3].

The paper proposes a bulky solution that is liquid dependent and it supports only transparent liquids.

The block diagram in figure 1 shows the process and working of smart saline level monitoring using:

- LM35 Temperature sensor,
- Tilt sensor.

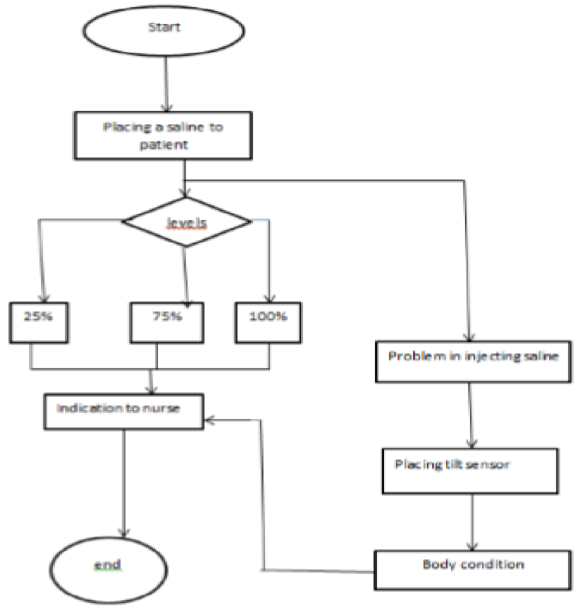


Fig 1 Block Diagram:

The ESP32 Powered Smart Saline Level Monitoring System Using MQTT-S as the Driving Network

The system explained in this paper is basically made up of four electronic components:

- Load Sensor,
- ESP32 Wi-Fi Chip,
- MQTT-S Broker/Server and
- MQTT-S Client.

The load sensor used is attached on the saline hanger rod and the saline bottle is hung on the same.[4] The system is developed such that each alerting level is converted to a varying voltage. In this way, different voltages lead to different levels on the saline bottle. Load sensor is used for this purpose. Therefore, the basic principle for the working of this system is that each marked level of saline weight represents some specific voltage output. The load sensor senses the weight of the bottle and converts in into equivalent voltage. This output voltage is fed in the ESP32 Wi-Fi chip. When the voltage mentioned as the threshold is achieved, then the message is displayed pertaining to the three categories provided in the paper. ESP32 will display the required output message such as FULL, ALERT and CRITICAL.[4]

The messages are generated under the following conditions.

- When the saline bottle is fully filled with the fluid, the condition is full.
- When 50% of the fluid or electrolyte is left in the bottle, the condition is termed ad alert in the paper.
- When only 10% of the initial fluid weight is left inside the bottle, the situation is termed as critical

This system uses MQTT as the network protocol for sending messages and displaying alerts to different display devices such as smartphones, tablets and laptops. As described by the author, in this system, ESP32 Wi-Fi chip plays the role of a MQTT-S publisher and electronic devices mentioned earlier are acting as MQTT-S clients or subscribers. MQTT-S broker is deployed on such configured and confirmed electronic machine/server which can handle the required number of MQTT-S publishers and clients or even more than that.
MQTT-S clients are connected to the broker via a TCP (Transmission Control) protocol. When ESP32 publishes a message, the MQTT-S broker will receive the message first and then forward it to the subscribed MQTT-S clients. [4]
The MQTT protocol being lightweight is efficient for handling message requests over the network. The solution provided does not define a flow stopping mechanism but provides an efficient alerting system.

Smart Saline Level Monitoring and Control System

This paper proposes a system which will function according to the different situations of the saline bottle which are explained below as follows:

- As soon as the power is turned on, the two IR sensors, TX and RX in this case, start detecting the drops of fluid dropping from the saline in the intravenous pipe attached to the patient's body.
- On the other hand, the microcontroller used in this system calculates the drop rate (drops per minute) detected by the IR sensors.

The system works on basic phenomenon of the number of drops left and the number of drops consumed by the patient.
The number of drops serve as the threshold for making conclusions in the system proposed. The microcontroller counts the number od drops detected by the IRs. According to the difference remaining, the time remaining for complete consumption of the electrolyte is calculated. As soon as the set level of emptiness is achieved at the decided critical level, the buzzer alerts the patients or the concerned authority. Motor is the device proposed in the paper that powers the mechanism for stopping the fluid drop rate.[1] The system architecture proposed by this paper is:

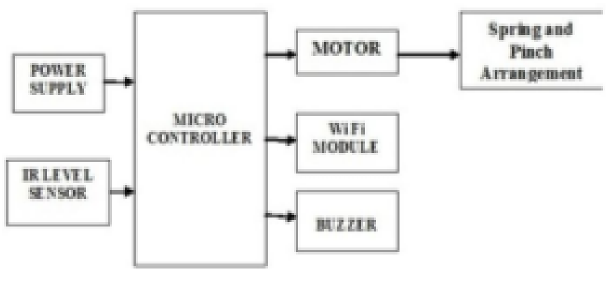


Fig 2 Block Diagram:

The system proposed in this system uses buzzer which might even disturb the patient's peace and nearby patients as well. The spring and pinch arrangement is an efficient way to control the back flow of the fluid. An app is also developed in this paper which displays the drop rate every instant. The system uses a separate Wi-Fi module and micro controller which is tedious connection. The IR sensor interferes with the fluid composition in the saline bottle and only saline can be used for detection, not any colored fluid.

IoT Based Saline Level Monitoring System

This system as mentioned by the authors of this paper, will perform under two different situations associated with the patient as mentioned further:

- Saline or the fluid in the bottle used or developed reaches the defined level as critical.
- The concerned war boys/nurses do not change the saline at the required time when it is fully consumed.

During the first condition fulfillment, once the saline after being constantly used by the patient, reaches its specified critical level, the IR sensor used in the system senses the level and starts its working. Once the level sensed by the sensor is fed to the micro-controller connected to the system, the micro-controller checks the collected information with the whole database as mentioned in the paper. As soon as the corresponding record matches, the controller retrieves it and sends an alert to the buzzer connected. The buzzer starts beeping along with which an alert is sent to the respective authority. The buzzer rings for a stipulated time limit set as mentioned by the authors. The retrieved information is also sent along with the alert. Internet is used as a medium for sending the message to the patient's associated doctors and nurses. If the patient is attended upon by any authority before the time limit set, they have to manually set off the buzzer once reaching the place. But, if there is no one who is attending the patient at the time of the alert, the second scenario will start to take place as mentioned.
The authors have set up the second scenario in such a way that when the buzzer starts beeping, if it is not set off within the time limit set, then the reverse flow of blood is to be stopped. To do this, a spring-dc motor mechanism is proposed in the paper. It is made with a clamp attachment which will move forward and backward depending on the compression and expansion of the spring attached.
As soon as the bottle empties, the IR sensor present near the neck of the bottle of saline senses the level of the fluid which will be zero in this case and will again power the buzzer by the micro-controller. This time, the buzzer will beep with maximized noise. If still, there is no one to look after the patient and the saline, the clamp will be driven to close the saline bottle with the help of a DC motor. The spring will be stretched moving the clamp in the desired direction as per the code and close the saline bottle tube. This stops the reverse flow of fluids from the patient to the bottle. A notification might also be sent to the nurse for total consumption of the fluid. [5].
The system gives an efficient mechanism for stopping the flow in reverse order but as far as the accuracy of the system is concerned, IR sensors are not fully efficient for the measurement. They even cause an interference with the existing fluid composition and leads to fluid used independence. No colored fluid can be used along with the system.

III. PROPOSED SYSTEM

System Components

The proposed system consists of following components:

- Load Sensor: The basic principle of working of a load cell is based on the properties of a piezoelectric material. As soon as any mechanical weight or load is applied on that material, deformation of the gauge takes place. This results in the change in the value of connected resistance changing the value of output voltage. We are using a 1 kg load cell to detect the weight of the electrolyte bottle after regular intervals. The load sensor can sense the weight from outside the bottle without interfering with the chemical composition of the electrolyte.
- ESP 8266 module: A wireless connection is required for notifying the nurses/doctors/control room admins about the status of the electrolyte for which we are using ESP 8266 module. It acts as a micro controller with a Wi-Fi availability module for the proposed system.
- A Display Screen/Device: For alerting the concerned authorities, a network connected display is required at the hospital. As soon as the critical level is reached, a notification will pop up at the receiver screen.
- Led light: A simple led bulb is used to provide a visual alert for the patient's relatives near the system to inform the doctor/nurses available.
- DC Motor: A dc motor is used to actuate the screw to turn clockwise after the electrolyte bottle turns empty to prevent the reverse flow of the patient's blood into the bottle.
- Screw actuated clamp Mechanism: A simple 3-d printed screw actuated mechanism as shown in Fig 3 is used to disconnect the intravenous tube of the electrolyte bottle with the patient. The screw can turn both clockwise and anti-clockwise. When turned clockwise, it will lead to moving of the clamp inwards and vice-versa.
- Database: A database at the user side is required for keeping the records of connected patients and even the patients whose electrolytes have been changed. The information related to the micro-controller reference number, the electrolyte number, room number of the patient and the status of the setup is stored in the database.
- Power Supply Unit: The main function of any power supply unit is to convert the main alternating current supply to the direct current for any electronic system to work efficiently. The most common use of power supply is in computers. Similarly, in this system too, the power supply used will provide current to the electronic components used.

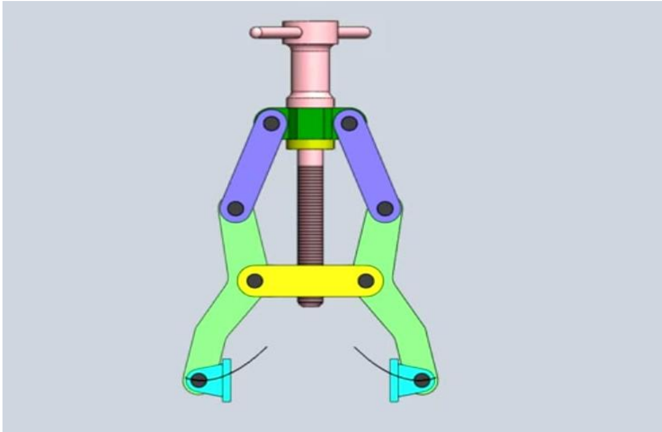


Fig 3 Screw Actuated clamp Mechanism

Working of the system

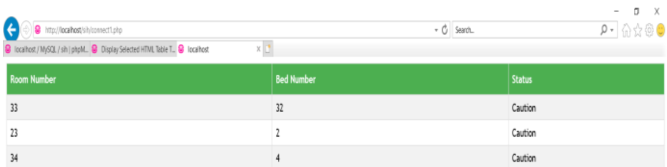
The system proposed is electrolyte independent and can be used with all sizes of the electrolyte bottle. The system is electrically powered and the voltage of 5V is required to power on the system.

As soon as the electrolyte bottle is hung on the stand and attached to the sensor via a specially designed 3-d printed hook, an initial weight reading of the bottle is recorded in the database designed by the micro controller. The database stores records of the electrolyte bottles with a reference number to each micro controller used with them. The load sensor senses the weight at regular intervals. The same is updated in the database regularly.

For enhanced patient safety and reduced risk probability, the system we have proposed is a three-level alerting system with a disconnection mechanism for prevention of the reverse flow of blood from the patient's body to the electrolyte bottle. The solution is a three-level alerting system. It works at three pre-defined critical levels of electrolyte in the electrolyte bottle. These are as follows:

- Level 1: As soon as the read value of the load reaches 30 percent of its initial value recorded in the database, an alert is sent to the respective authorities that is nurses/doctors/control room admins with the details of the patient concerned.

  A web page as shown in figure 1.4 using HTML and CSS is prepared for displaying the notification of all the electrolyte bottles requiring immediate attendance. It is a sample notification page for database stored at the localhost.



Room Number	Bed Number	Status
33	32	Caution
23	2	Caution
34	4	Caution

Fig 4 Screw Actuated clamp Mechanism

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- Level 2: The sensor keeps reading the weight of the bottle and a LED starts blinking as soon as the weight of the bottle further decreases to 20 percent of its initial weight. In this way, any person present in that room might be able to identify the light and inform the attending doctor.
- Level 3: If further no one switches off the LED or attends on the customer, a notification is again sent with a danger alert to the control room/ nurses/doctor concerned and the status is updated in the database. As soon as the electrolyte gets fully consumed without being disconnected or refilled manually, the microcontroller powers the DC motor. The motor actuates the screw powered clamp shown in Fig 3 which disconnects the patient with the electrolyte bottle. This prevents the reverse flow of blood.

As soon as the DC motor is powered, it will rotate the screw clockwise leading to the clamp movement inwards toward the tube. When the screw is completely turned clockwise, the clamp will block the intravenous tube.

This mechanism being 3-d printed does not react with bio medical components near the patient.

After the intravenous tube is blocked, the status of the electrolyte bottle will be updated in the database as empty. The record of that bottle will be deleted from the current active records and moved restored in the past records table. It can be retrieved by database admins.

The system architecture is as shown below:

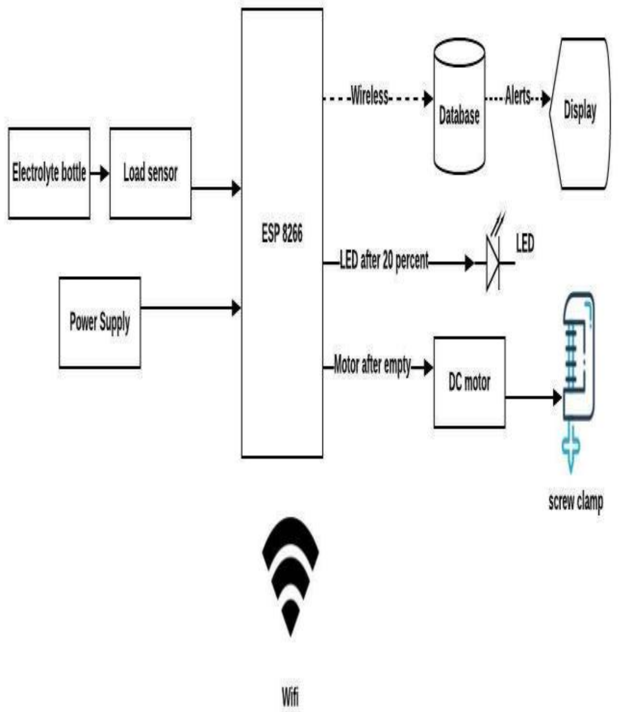

Fig 5 System Architecture

IV. ADVANTAGES

1. Eliminates the need of a caretaker to keep an eye on the bottle level
2. Makes the whole process more secure
3. Keeps a record of the bottles connected in the database
4. Reduces efforts of the healthcare specialist
5. The system is electrolyte or fluid independent and any fluid can be used.
6. The proposed solution is not specific to a size or shape of the electrolyte bottle making it robust.
7. The designed solution is not bulky.
8. Two saline bottles can be connected to a single micro controller.
9. The database is designed in such a way that previous records of the patients are also stored.
10. The proposed solution does not interfere with the chemic
11. The system is easily adaptable and programmable.

V. RESULT

The alert pops up is displayed in the form of a table developed using HTML and CSS on the localhost. The database is prepared in SQL using phpMyAdmin that contains of two tables:

- One for the current patient usage of the microcontroller and the saline attached. It contains fields like room number, microcontroller_ reference number, bed number, current timestamp and patient registered number.
- Another for storing the past records of the patients and the saline bottles used. It contains all the details of the precious table for the electrolyte bottles disconnected.

As soon as any electrolyte bottle whose record is maintained in the database reaches the critical level, its alert is displayed in the form of a table at the display screen. The page is refreshed after every two seconds for updated status.

VI. CONCLUSION

The proposed system is an IoT based system that eliminates the need of a nurse/caretaker to continuously monitor the electrolyte level in a saline bottle. We also proposed a DC motor-controlled screw actuated clamp mechanism to stop the flow of the electrolyte. The wireless system also saves the data of the bottles connected and can be implemented in hospitals easily. The future work in the system may include a better connection with more than one device to send the notification/alert on.

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