Original Article

IoT based Saline Monitoring System

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Abstract

With the increasing world population, the need for health prevention is also increasing. In these recent years, there is a rapid advancement in clinical care due to the technological advancements in the various fields of sensors and micro-controllers for assuring fast recovery of patients in the hospitals. The major and crucial necessity of the hospitalized patients is that each patient ought to be provided with a better treatment and observation and ought to be provided the right measure of vital nutrition at the right time. Saline solution is used for the covid patients to reduce the inflammation in different parts of the body such as lungs, heart, kidney and skin. Among the various treatments, the saline therapy is the most important treatment that numerous patients receive from the hospitals. Whenever a saline is fed to the patients, the patient needs to be persistently administered by a nurse or a care-taker. But unfortunately, there are some circumstances like patient's blood flow backwards into the saline tubing system. The proposed saline level monitoring and automatic alert system helps to protect the patients in this Covid time and to provide them with safety during saline feeding hours.

Keywords: Internet of things, Saline, Arduino, sensors, Application, Thingspeak, Cloud, Monitoring.

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INTRODUCTION

Internet of Things commonly referred to as IoT is the "next big thing" in the world right now with an expected presence of around 30 billion devices by the end of this decade. The Internet of Things (IoT) portrays the network of physical object "things" that are installed with programming, sensors, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the internet. In other words, it's a physical object that connects to the Internet. In many cases, IoT systems connect highly specialized devices with limited programmability and customizability.

The Internet of Things is one among the top emerging technologies which is being widely used in Machine Learning, Embedded Systems, Smart homes, Smart city, Self-driven cars, Telehealth, Farming, Analytics, Flight services, Health, Traffic monitoring, Home Automation, Online Shopping and many more.

Humans are susceptible to respiratory illnesses caused by Corona viruses. Hypertonic saline solution is utilized for the Covid-19 patients to reduce the inflammation in different parts of the body such as lungs, heart, kidneys and skin and furthermore it is utilized for providing extra water to rehydrate people or supplying the daily water and salt needs of a person who is unable to take them by mouth. Yet, hypertonic Saline may cause serious side effects including fever, decreasing the oxygen level and the pulse rate of the patient.

In this process, continuous monitoring is required. The saline drop rate is adjusted utilizing the drip chamber which delivers the solution at the required amount into the patient body. Whenever there is a saline dripping, there is a need for a person to monitor the glucose level and the glucose flow rate may be at regular intervals of time. The concerned patient should be in careful observation. Here the nurses/ doctors should screen the level of the saline fluid consistently which is given to the patient because after completion of the saline fluid there are two possibilities, the blood may flow backward from the patient's body to the saline bottle due to low pressure present in the bottle and high pressure of blood flowing in the patient body or there are also chances that the air present in the saline bottle enters in the form of air bubbles from the saline bottle into the blood stream and stops the flow of blood prompting the risky state of the patients. To avoid this risky states the nurses/ doctors should monitor the patient consistently. In this pandemic situation due to their hectic schedules this might be difficult for the nurses/ doctors.

Thus an automated system of monitoring the Saline Fluid which is proposed in this paper to save the life of patient and furthermore to reduce the consistent monitoring of the fluid in the hospitals when there are numerous patients assigned to few nurses. This system is also used to check whether the patient is suffering from high temperature or the oxygen level or the pulse rate is decreasing by using the various sensors.

This might accommodate medical staffs for observing the saline level from a distance and reduce the continual on-site monitoring by the doctors and nurses.

After the saline bottle gets completed, to control the flow rate of the fluid stepper motor is utilized which will squeeze the capillary tube so that the progression of the saline fluid gets stop and there won't be any opportunities for in reverse progression of blood and entering of air bubbles into the patient's body.

A XAMPP server is used to display the patient's details such as temperature, pulse rate and oxygen level of the patient. XAMPP includes Apache, PHP, and MySQL. An IoT based saline monitoring web page was developed using PHP and MySQL. The sensors sense temperature and pulse rate of the patients' and to display those results in web page. And also the patient history will be stored on the web server and doctor can access information whenever needed from anywhere and need not physically present.

The rest of the paper is organized as follows: Section two focuses on the related works, the Section three describes about the proposed work and the section four is provided with the references.

Related Works

Kriti Ojha et al. [1] proposed the IoT based saline level monitoring system**.** Level sensor is used in this system which provides the accurate readings. If the saline level goes below the threshold point, notifications sent to the nurses by using bluetooth device but it slowly drains the battery of the cell phone. P. Kalaivani *et al.* [2] proposed this system which monitors cardio patients using ECG sensor in addition to saline level. All the patient details will be displayed in a LCD monitor.

Mansi G. Chidgopkar et al. [3] proposed the Automatic and low cost saline level monitoring system using wireless Bluetooth module and cc2500 trans receiver. This system monitors the saline flow and it also predicts the remaining time to empty the saline. There is a buzzer which is fixed near to the patient bed and when the saline is going to empty, the buzzer starts to ring. Sagnik Ghosh *et al.* [4] proposed Development of intelligent and smart saline bottle. In this system linear regression algorithm is used to predict the future moment when the saline bottle needs to be changed by the nurses/ doctors.

Anusha Jagannathachari et al. [5] proposed Saline level indicator. This system monitors the saline flow and if the saline gets over with the help of the DC motor and a spring which will prevent the reverse flow of blood in the tube. Sanjay. B et al. [6] proposed IoT based drips monitoring at hospitals. This system monitors the saline level with a different component called load cell and also sends the alert messages if the saline gets completed.

Karthik Maddala et al. [7] proposed the system which monitors the saline flow and it also displays the level of the saline in a LCD display (16*2). When the saline gets over an alert message is sent to the nurses/ doctors. Ashika A. Dharmale et al. [8] proposed IOT Based Saline Level Monitoring & Automatic Alert System. In this system three IR sensors are used to indicate the level of the saline. This system also stops the flow of saline by using a micro servo motor. All the patient and saline details are stored in the database for the future use.

Vyankatesh Gaikwad et al. [9] proposed this system to monitor the saline level by using an Ultrasonic sensor and it also sends a notification to nurses using the wifi module. In this system the patients can be accessed by using a mobile application. Pooja Pandit Landge et al. [10] proposed Smart Saline Level Monitoring and Control System. This system uses IR sensor to monitor the saline level and a DC motor is utilized to stop the flow of saline. The patient details will also be displayed in an android application.

B. Kiruthiga et al. [11] proposed this system to monitor the saline level and the heart rate of the patient. A relay driver and a solenoid valve is used to stop the flow of saline. Using a GSM module an alert message is sent to the nurses/ doctors. S. Velmurugan et al. [12] proposed this system which uses flow sensor and a level sensor to monitor the flow rate of the saline and the level of the saline respectively. In this system 4 solenoid valve is used to stop the flow of saline automatically by using a UART wifi module.

N. Y. Suma keerthi et al. [13] proposed Intravenous infusion monitoring system. This system used to monitor the saline level and also monitors the saline droplets rate. The Firebase realtime database is used to store the sensor data that has been collected from the Raspberry pi and then it sends the alert message. Sakshi D. Ambadkar et al. [14] proposed NRF Transceiver based Saline Level, Health Monitoring & Control System. This system monitors the saline level, heart rate and temperature of the patient. It also stops the flow of saline by using a servo motor. This system also sends the message if there is any abnormal in the patient's health.

Zeng Chen et al. [15] proposed Enhancing Healthcare through Detection and Prevention of COVID-19 Using Internet of Things and Mobile Application. This framework proposed to monitor the saline level, patient's heart rate and temperature. The sensors data are sent to the firebase database and the patient details can be viewed through the android application. Md. Milon Islam et al. [16] proposed this system which monitors the temperature of the patient and also the patient's room. By using the ESP32 module the patient's data are sent to the thingspeak where patient's information can be seen from anywhere.

Mustafa A Al-Sheikh et al. [17] proposed this system to monitor the temperature, heart rate, oxygen level and ECG of the patient. All the patient details can be monitored by using a health monitoring application in android phones.

S.NO	AUTHOR	COMPONENTS USED	ADVANTAGES	LIMITATIONS
1	Kriti Ojha et al (2020)	Level sensor, IR sensor, micro Controller ATMEGA 328 and a Bluetooth device.	level sensor provides the accurate readings	Bluetooth device is that it slowly drains the battery of the cell phone
2	P. Kalaivani *et al. (2020)*	ECG wearable clamp, ECG wearable sensor AD8232, IR sensor, LCD (16 * 2) and Arduino UNO R3	ECG sensors consume very little power, and are fast, accurate	AD8232 which causes Increase in difficulty in placement of electrodes to achieve better results and also gives false alarms
3	Mansi G. Chidgopkar et al. (2021)	IR sensor, buzzer, Arduino ATMEGA328, LED, battery, wireless Bluetooth module and cc2500 trans receiver	CC2500 Wireless Trans-receiver requires no extra hardware and no extra coding to turn your wired communication into wireless one	Bluetooth security is weak compared to Wi-Fi and other wireless data standards
7	Sagnik Ghosh *et al.(2021)*	Node MCU, IR sensor, Load Sensor, wifi module, red LED, buzzer	Linear Regression is the best to use because it's less complex as compared to other algorithms	Thingspeak is not very secure.
8	Anusha Jagannathachari et al. (2020)	Arduino controller ATMEGA328, Buzzer, DC motor, spring, IOT server, IR sensor	spring is it can stop the reverse flow of the blood in the tube	DC motors have high initial cost and increase in maintenance cost
9	Sanjay. B et al. (2019)	Arduino AT Mega 328, HX711 Amplifier, Load Cell, LED and GSM Module Sim 800a.	Sending the alert messages three times to the nurses/ doctors	The cost of GSM is so high
10	Karthik Maddala et al. (2019)	Arduino Uno ATMEGA328, LCD (16*2), Load Cell, Breadboard, Hx711 module, I2C module, GSM 900A	phone gets notification the staff get alerted immediately and there is no chance of backflow	cost of GSM is so high
11	Ashika A. Dharmale et al. (2020)	Node MCU microcontroller, IR Sensors, Rubber Bands, Micro Servo Motor, Buzzer, LED and Power Supply Unit.	Micro servo motor is used to automatically stop the flow of saline immediately after the saline bottle is completely empty.	By using many LEDs it can cause heat to the whole system.
12	Vyankatesh Gaikwad et al. (2019)	Ultrasonic Sensor HC-SR04, microcontroller Node MCU ESP-8266 and Wi-Fi module	ultrasonic sensor has higher sensing distance	the range offered by the wifi network is limited
13	Pooja Pandit Landge et al. (2019)	IR level sensor, buzzer, motor, micro controller Arduino ATMEGA328, spring and wifi module	spring controls the reverse flow of blood into the saline bottle	the range offered by the wifi network is limited
14	B. Kiruthiga et al. (2020)	Level sensor, heartbeat sensor, indicator panel, Arduino UNO ATMEGA 328, transformer, rectifier, load sensor, LCD (16*2), GSM module, level converter and IOT module	The load sensor is that it gives precise measurements	the GSM module is that the cost is very high
16	S. Velmurugan et al. (2020)	Arduino ATMEGA 328, LCD display (16*2), wifi module, Solenoid valve, flow sensor, level sensor	The level sensor provides the accurate readings	when lots of users are getting access to internet via same wifi network then the speed of transfer data comes down
17	N. Y. Suma keerthi et al. (2020)	level sensor, Raspberry pi, IR sensor, Laser sensor	level sensor provides the accurate readings	Raspberry pi is that it does not run on the windows application
19	Sakshi D. Ambadkar et al. (2021)	LED, LCD display (16*2), GSM, buzzer, NRF module, load cell, heart beat sensor MAX30100, temperature sensor LM35 and micro controller ATMega328	NRF module is that it has high stability, low power consumption and low cost	GSM is that it is of high cost
21	Zeng Chen et al.(2021)	Node MCU ESP8266, wifi module, LED, DHT11 sensor, pulse sensor	DHT11 has excellent quality, fast response, anti-interference ability and high cost performance	when lots of users are getting access to internet via same wifi network then the speed of transfer data comes down
24	Md. Milon Islam et al. (2020)	ESP32, heart rate sensor, body temperature sensor, room temperature sensor and CO sensor	the ECG sensor is to transmit data in real time to a smartphone or computer	Thingspeak is that it is not very secure
26	Mustafa A Al-Sheikh et al. (2020)	heart rate sensor (MAX30102), Spo2, Arduino UNO, ECG sensor, body temperature sensor (LM35) and nodeMCU	of LM35 sensor is that is does not require any external calibration	Using spo2, by carbon monoxide poisoning it may not produce an alert in a pulse oximeter

Proposed Work

The architectural design for the IoT based Saline Monitoring System is shown in Figure 1. The proposed IoT based saline monitoring system has four modules.

A) Assemble the hardware components

The hardware components used in this project are Wireless water level sensor XKC-Y25, Pulse sensor MAX30100, Temperature sensor DHT11, Arduino ATMEGA328, Arduino mega, GSM module SIM900A and servo motor. The above three sensors are connected to the Arduino and when there is any discrepancy seen in patient's health, then the alert messages will be sent to the mobile devices through the GSM module. A servo motor is connected to stop the flow of saline which prevents the blood may flow backward from the patient's body to the saline bottle or the air bubbles may enter into the blood stream from the saline bottle. Figure 1 shows the components connection.

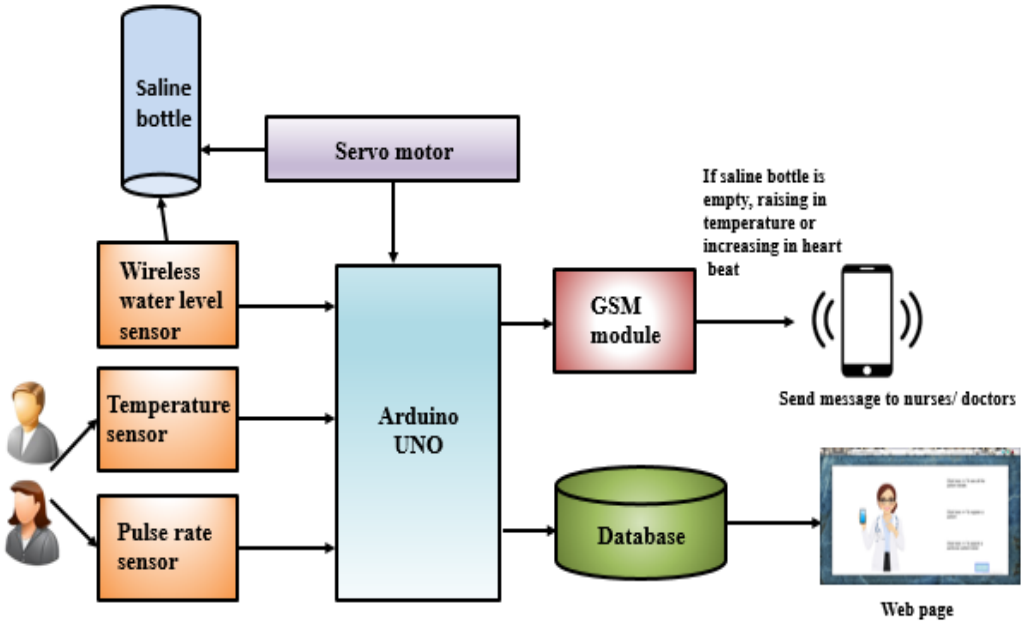

Figure. 1 (System diagram)

B) Saline level prediction

The saline fluid level is predicted by using the Wireless water level sensor (XKC-Y25). This sensor is to indicate whether the saline bottle has a high or low saline level. The sensor consist of a LED light and initially this light will be on when the saline bottle has the fluid and it goes off when the saline bottle is empty. This sensor is connected to arduino. The Arduino software which an open source helps to read the sensors and the results can be seen via the serial monitor of the Arudino. The patient's history are stored in a database and the details will also be available in web application.

When the saline fluid gets finished, an alert message is sent to the patient's mobile device and a servo motor is fitted to the drip chamber which stops the reverse flow of blood from the patient's body by squeezing the saline tube. Figure 2 shows the connection of wireless water level sensor and a servo motor.

Algorithm for prediction of saline fluid

1. Connect the sensor to Arduino
2. Initial saline_level=0
3. Place the sensor in saline bottle
4. If (saline_level == 0)
5. Print "The saline bottle is not empty"
6. Else if (saline_level ==1)
7. Send the alert message to nurse
8. Print "The saline bottle is about to empty"

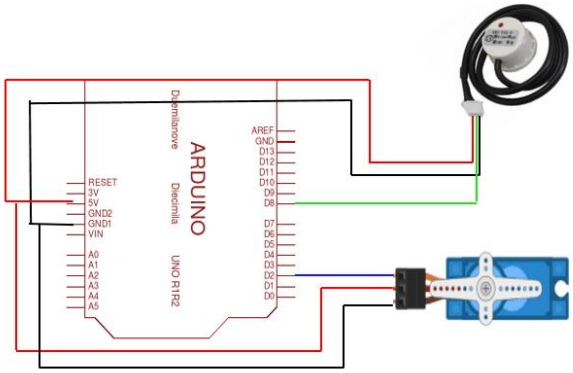

Figure 2 Arduino UNO connected with Wireless water level sensor and servo motor

C) Effects of saline fluid detection

The most common effects of saline fluid are raise in temperature of the patient and increases in heart rate. The objective of this module is to sense the patient's temperature and pulse.

Figure 3 shows the connection of wireless water level sensor, temperature sensor and heart rate sensor to Arduino. To detect the temperature of the patient, DHT11 (Digital temperature and humidity sensor) is used. This sensor contains a thermistor which is utilized to measure temperature. Inside this sensor, there is also a humidity sensing component along with a Thermistor. The DHT sensor is placed to the patient's hand to predict the body temperature whether it is normal or abnormal.

The second effect of injecting the saline into the human body is that it can increases the heart beat which may cause serious issue to the patients. To detect the heart rate of the patient, Pulse oximeter MAX30100 sensor is used. This sensor helps to monitor the heart rate and the level of the oxygen in blood. This sensor is connected to Arduino and it can be easily clipped onto a fingertip/ earlobe of a patient. The pulse sensor is well designed heart rate sensor for Arduino. A 24-inch color Coded cable with header connectors. The front side of sensor that is heart logo make contact with a skin and a small round hole for LED glows from backside of sensor. If the heart beat is between 50bpm and 90bpm, then the patient has normal heart beat otherwise the alert message will be sent to the nurse.

Algorithm for prediction of patient's temperature

1. Connect the sensor to Arduino
2. Initial saline_level=0
3. Place the sensor in saline bottle
4. If (saline_level == 0)
5. Print "The saline bottle is not empty"
6. Else if (saline_level ==1)
7. Send the alert message to nurse
8. Print "The saline bottle is about to empty"

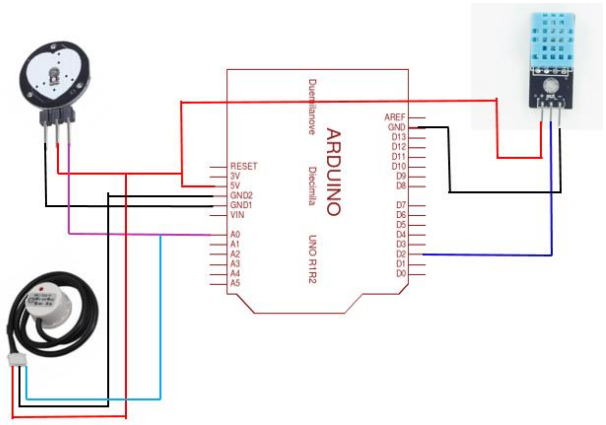

Figure 3 Arduino connected with Wireless water level sensor, temperature sensor and heart rate sensor

Algorithm for prediction of patient's pulse rate

1. Connect MAX30100 to the Arduino
2. Place the sensor to the patient's finger
3. Prints the heart rate and the oxygen level in the blood
4. If (heart rate >=50 and heart rate <=90 and oxygen_level >95 and oxygen_level <99)
5. Print "NORMAL"
6. If (oxygen_level <95)
7. Alert message is sent to the nurse
8. Print "OXYGEN LEVEL IS ABNORMAL"
9. If (heart rate > 100 or heart rate <50)
10. Alert message is sent to the nurse
11. Print "HEART BEAT IS ABNORMAL"

D) Retrieve the data from the sensors and store it in the database

A XAMPP server is used to display the patient's details such as temperature, pulse rate and oxygen level of the patient. XAMPP includes Apache, PHP, and MySQL. An IoT based saline monitoring web page was developed using PHP and MySQL. The sensors sense temperature and pulse rate of the patient's and to display those results in web page.

E) Display the patient's information in mobile device

A GSM modem (Global system of mobile communication) is a specialized type of modem or phone hardware on small PCB which accepts a SIM card, and it is just like a mobile phone. A sim card is necessary for the GSM module.

After connecting all the components and sensors to the GSM, this GSM module allows to send the messages as an alert to the nurses/ doctors if there is any abnormal conditions in patient's health.

And also the patient history will be stored on the web server and doctor can access information whenever needed from anywhere and need not physically present.

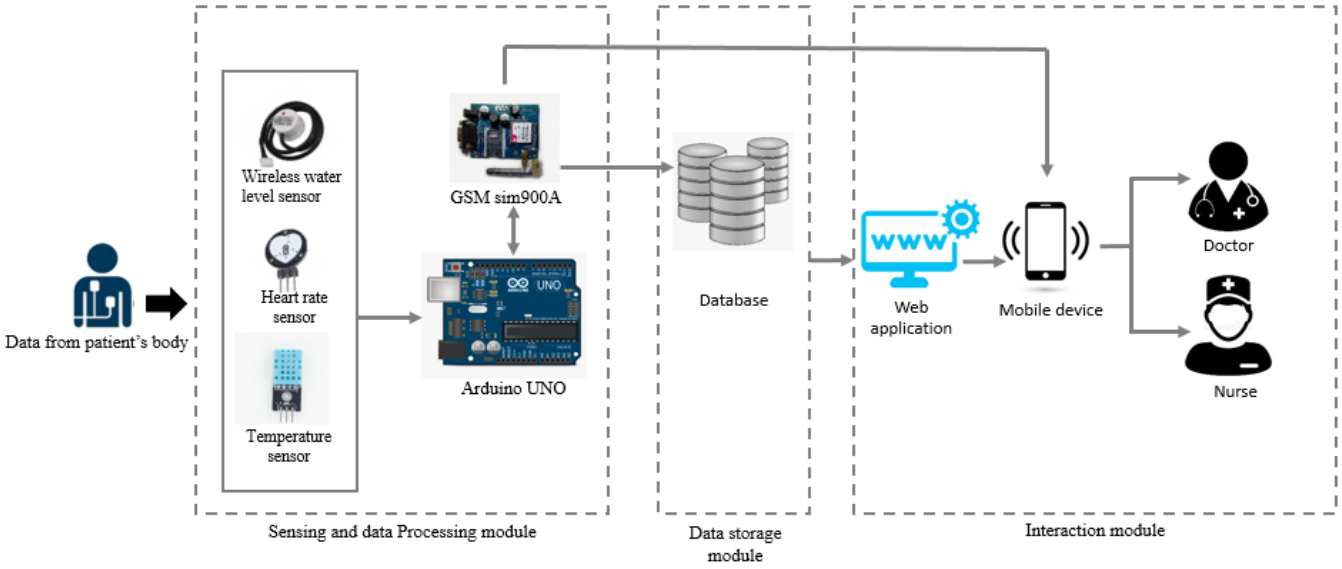

Figure 4 System architecture

Experimental Results

As the entire function of the system is systematized utilizing a hardware device and an application interface, the implementation phase can be categorized into hardware implementation and software implementation.

4.1 Hardware implementation

A) Hardware Model

Arduino, XKC-Y25 wireless water level sensor, DHT11 sensor, pulse rate sensor, GSM module and Servo motor are connected together and form the sensors the data are stored in the database. The below diagram is the IoT based Saline monitoring system model.

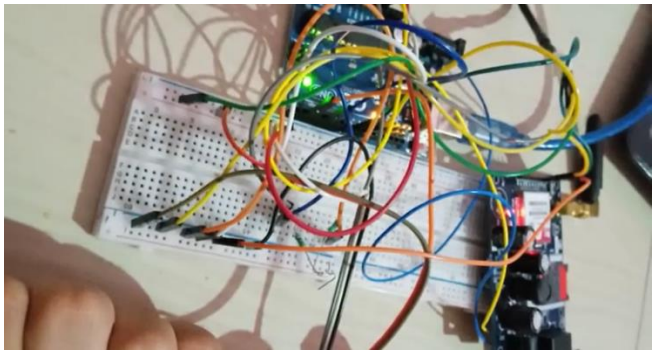

Figure 5 IoT based Saline monitoring system model

The table 1 indicates the types of sensors used and the outcome of the sensors.

Table 1 (Types of sensors used)

SENSORS	Saline level	Body temperature	Heart rate	humidity	Oxygen level	Heat index
Wireless water level sensors	✔					
Temperature sensor		✔		✔		
Pulse rate sensor			✔		✔	✔

The table 2 indicates the iteration for the saline level, temperature, heart rate and humidity.

Table 2 (Output in serial monitor)

Iteration	Saline level	temperature	Heart rate	humidity
1	1	32.2	36	48%
2	1	33.7	48	50%
3	1	34.5	75	50%
4	1	36.3	83	50%
5	0	37.4	98	50%

The table 3 indicates the time, heart rate, temperature in Celsius and Fahrenheit, heat index in Celsius and Fahrenheit and the saline level where the values are taken from the sensors by using PLX-DAQ.

Table 3 (Output in excel sheet)

	A	B	C	D	E	F	G	H
1	Time	Heart rate	Humidity (%)	Temperature (C)	Temperature (F)	Heat index (F)	Heat index (C)	Saline level
2	22:07:46	21	46	34.2	93.56	99.52	37.51	0
3	22:07:54	38	53	34.7	94.46	106.05	41.14	0
4	22:07:57	37	55	34.7	94.46	107.52	41.96	0
5	22:08:17	86	65	35.2	95.36	118.85	48.25	0
6	22:08:20	52	66	35.2	95.36	119.84	48.8	0
7	22:08:22	65	66	35.2	95.36	119.84	48.8	0
8	22:08:25	54	67	35.2	95.36	120.84	49.35	0
9	22:08:28	56	67	35.2	95.36	120.84	49.35	0
10	22:08:30	57	68	35.2	95.36	121.86	49.92	0
11	22:08:33	60	68	35.2	95.36	121.86	49.92	0
12	22:08:35	69	69	35.6	96.08	125.57	51.98	0
13	22:08:38	70	69	35.6	96.08	125.57	51.98	0
14	22:08:40	72	69	35.6	96.08	125.57	51.98	0
15	22:08:43	73	69	35.6	96.08	125.57	51.98	0
16	22:08:46	75	70	35.6	96.08	126.67	52.6	0
17	22:08:48	78	70	35.6	96.08	126.67	52.6	0
18	22:08:51	78	71	35.6	96.08	127.8	53.22	0
19	22:08:53	78	71	35.6	96.08	127.8	53.22	0
20	22:08:56	100	72	35.6	96.08	128.94	53.86	0
21	22:09:51	79	76	36.3	97.34	139.25	59.58	1
22	22:10:09	79	77	36.3	97.34	140.58	60.32	1

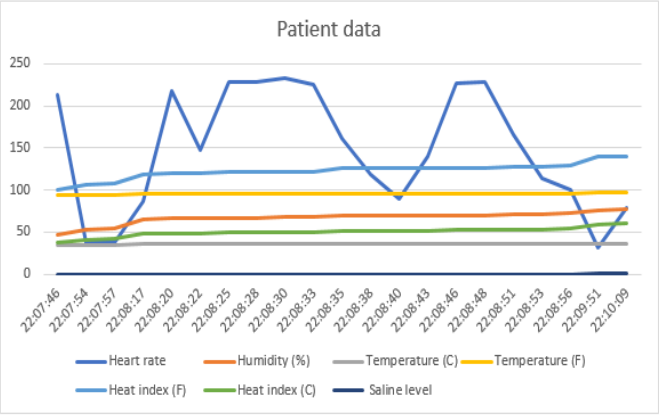

Figure. 6 Patient data

Figure 6 shows the live heart rate, humidity, temperature in ^{o}C and ^{o}F, heat index in ^{o}C and ^{o}F and the level of the saline in the graphical format with delay of 2 seconds. The live data is updated in a uniform interval.

4.1 Software implementation

A) Login page for nurses, doctors and the admin

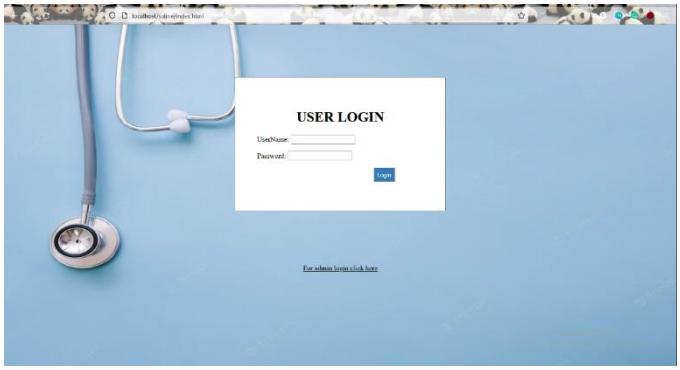

Figure.7 Login page

Figure 7 shows the login page of the nurses/doctors/ admin account where the nurses/ doctors can view the patient details and the admin account is used for updating the database if any new nurses/ doctors are appointed.

B) Register page

Figure. 8 Register page for the new patients

Figure 8 shows the registration of new patient page which will be registered by the nurses which consists of patient ID, name, age, gender, blood group, phone number and address.

C) Patient details

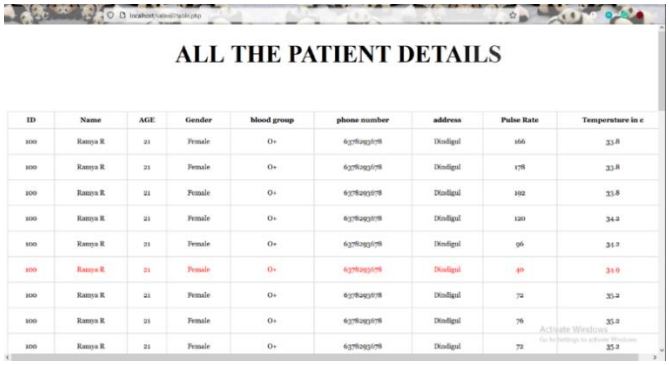

Figure. 9 All patient details in webpage

Figure 9 shows the total patient details who are admitted and also the discharged patients.

D) Search data by id

Figure. 10 All patient details in webpage

Figure 10 shows the search page which is used to see the particular patient details. By entering the particular ID of the patient, this page displays all the personal details of the patient like name, ID, age, Address, blood group, phone number and also it displays the health details of the patient when they were admitted.

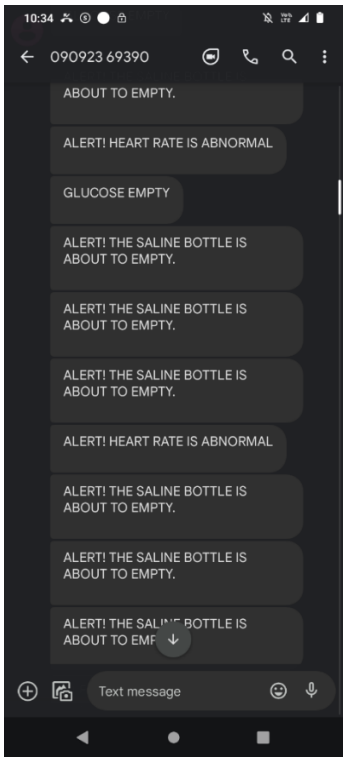

Figure. 11 Alert message to the doctor

Figure 11 shows the alert message sent to the nurses/ doctors when the patient is in emergency. That is, when the saline bottle gets empty and when the patients' health varies like increasing in temperature and also if decreasing/ increasing of heart rate of the patient.

CONCLUSION

This paper proposes the automated approach to monitoring the Saline Fluid in the bottle and furthermore to stop the flow of saline using solenoid valve. The proposed system is suitable for use in hospitals via a computer or smartphone, doctors or nurses can screen the Saline level, temperature, oxygen level in the blood, and any patient's heart rate can be accessed at any time and from any place. As the entire proposed framework is automated, it requires exceptionally less human intervention. It is particularly useful for the nurses especially at the hospitals where numerous patients are alloted to 2-3 nurses. Consequently, this system is user friendly and any naive user with a little training can easily utilize this system. It can be reused for the next saline bottle.

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