International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2020): 7.803

IoT Based Drip Infusion Monitoring System

Satwik Tanwar[1], Deepa. K[2], Riddhi Maniktalia[3], Ritvik Billa[4]

[1]School of Computer Science and Engineering, Vellore Institute of Technology, Vellore, India
satwiktanwar2002[at]gmail.com

[2]Department of Software Systems, School of Computer Science and Engineering, Vellore Institute of Technology, Vellore, India
deepa.k[at]vit.ac.in

[3]School of Computer Science and Engineering, Vellore Institute of Technology, Vellore, India
maniktaliariddhi[at]gmail.com

[4]School of Computer Science and Engineering, Vellore Institute of Technology, Vellore, India
ritvikbilla[at]gmail.com

Abstract: ***During recent years, we have seen much technological advancement which help to take better care of patient's health and assure them fast and safe recovery. The most basic item necessary is competent patient care in hospitals, as well as proper management of fluid and electrolytes. In hospital almost all patients, mainly ICU patients, have to regulate the volume of fluids and electrolyte into the bloodstream 24X7 which is done using drip. These drips need regular monitoring or changing to maintain constant flow of fluids or to prevent any infection to patients. Though this system is simple, overcrowded hospitals and the risk of deficiency of nurses can put patients at health risk which can deteriorate patients' health more aggressively or in worse case it can lead to death. Almost in all hospitals, nurses or the hospital staff are responsible for monitoring the drip level. But unfortunately, because of their hectic schedule, the observer may forget to change the bottle at the appropriate time. During the pandemic, hospitals were overrun with patients, and nurses were unable to do manual regular checks on the drip conditions and drip level of every patient, even after working extra shifts. Many patients even died due to not being able to get proper care from nurses. The next step in providing more effective and easy healthcare is to automate such vital procedures. To overcome this critical situation, we are proposing an IoT(Internet of Things) based Drip Monitor System using Arduino UNO which eases the process of measuring and solves the issues of bubble formation in drips.***

Keywords: Efficient, automation, Arduino UNO, IV infusion, drop rate monitoring, bubble formation

1. Introduction

Drip Monitoring Therapy is the process of passing nutrients, food and necessary medicines directly in your bloodstream, with the help of a small tube called a catheter, bypassing your digestive tract. These fluids help maintain a patient's hydration, electrolyte and blood sugar levels while undergoing surgical procedures. A bottle filled with the necessary fluid medication is hung at a level higher than the patient's body to provide the fluid with a pressure created by gravitational potential energy, which overcomes the circulatory pressure. The existing Drip Monitoring system is manual and requires a nurse or a doctor to keep a check on the patient's infusion setup. Traditionally, they need to approximate the time a bottle will take to empty and regular rounds are required to regulate the flow rate, and avoid any bubble formation which makes the manual Drip Monitoring system prone to human error. In most cases, the bottle is replaced when it is fully empty. The time it takes a nurse to replace an empty bag varies depending on factors such as the amount of medicine administered, variations in back pressure owing to systolic-diastolic and non-quantifiable dilation or contraction of veins. Since, this procedure is dynamic in terms of measurement, comprehensive monitoring that can warn nurses at precise percentages depending on the type of the electrolyte in the drip and the time required to replace the IV(Intravenous) infusion bag is required.If nurses do not stop or replace the infusion at the appropriate moment when the bottle is empty and the infusion procedure is complete, it might result in an air embolism in the IV tube, which can be fatal or harm the patients' health. Because a minor human error might jeopardise a patient's health, constant monitoring is essential. In our country, there is a significant disparity in the patient-to-nurse ratio. Every patient's drip rate cannot be monitored by nurses properly. Due to this, our proposed model of Drip Infusion Monitoring System is the future of our healthcare industry.

This project proposes a method for hospitals to efficiently monitor drip infusion levels. Our proposed system consists of an Ultrasonic sensor to detect the level of fluid and a light sensor to detect any bubble formation in the IV infusion bag. A control mechanism can alert the nurses or doctors if the fluid levels in the IV infusion bag drops down a certain level to prevent air embolism and avoid reverse flow of blood.

After that it's up to the nurse if he/she wants to continue or change the IV bag. This project significantly improves the overall efficiency of the hospital personnel. Our main aim of this project is to provide a reliable, cost effective and automatic drip monitoring system which anyone can implement or operate easily without any problem.

Since necessary presence or regular monitoring of patients is not required, the proposed method will greatly benefit hospital staff. It also prevents any chance of human error caused due to overflow in the hospital. This idea not only provides an automatic & reliable way to monitor the fluid percentage in patients IV drip but also to detect air bubble formation which causes risk to patients health.

2. Development of the System

The proposed system makes use of Arduino Uno, HC SR-04 Ultrasonic Sensor, Light sensor, a light source and ESP8266-01 Wi-Fi module. The Arduino Uno will be connected to the ESP8266 modules and two sensors i.e., HC SR-04 and LDR. The Ultrasonic sensor will be attached to the top of the drip along with a small light source and LDR will be placed at the bottom of the infusion bottle. Arduino UNO is used to retrieve and calculate sensor data. The calculated sensor values will be conveyed to the ThingSpeak website via the ESP8266 module which will then be retrieved by the android application to notify the nurses about the fluid levels and formation of bubbles in the drip.

a) Arduino Uno

In this project we use an Arduino Uno board which is equipped with ATmega328P, an 8-bit AVR microcontroller chip, which is the main heart of Arduino Uno board. It executes or runs code to power up or reset the Arduino Uno after programming without the use of external hardware. [1][2]

There are 14 digital input I/O pins out of which 6 can be used as PWM outputs, other than this it also has 6 analog input pins to read analogy sensor, they have all functionality of a GPIO pin (General purpose input/output pin). The pin operates at 5 V, although the board can get external supply from 6 to 20V. But it’s recommended to operate in a range from 7 to 12 V, as if voltage is lower than 7 the board may become unstable and if voltage is higher than 12 it can damage the board from overheating. To produce a clock signal, we have a 16MHz ceramic resonator (CSTCE16M0V53-R0). It is used to deal with time related issues or work, like to switch ON & OFF some device which is connected to an Arduino Uno board after every 5 minutes. The ATmega328P chip contains 32 KB of flash memory, of which 0.5 KB is utilised by the bootloader. [1][2]

To get the Arduino Board up and running, we can either connect it to the computer through a USB cable or give external power using an AC to DC converter or battery. Connect the adapter to the board by connecting it to the power jack through the GND and Vin pins. It also has a ICSP header and reset button. [1]

The Arduino Uno board is used to regulate the operation of the suggested system since it controls the sensors, processes the data and then delivers it to the Firebase website via the ESP8266 WiFi Module.

b) HC SR-04 Ultrasonic Sensor

An ultrasonic sensor generates high-frequency sound waves and detects the echoes generated by the target or object. These sensors are helpful in situations that need non-contact sensing. The HC-SR04 has a 5V DC power supply, a current of less than 2 mA, an angle of less than 15 degrees, a distance range of 2 cm to 400 cm or 1 inch to 13 foot, a resolution of 0.3 cm, a measuring angle of 30 degrees, and a trigger input pulse width of 10 microseconds. The sensor contains four pins labelled VCC (5V DC), trigger (input), echo (output), and GND (ground). It consists of two ultrasonic transducers, one of which acts as a transmitter which converts electrical signal to 40KHz into sound pulses and other as detector, it is connected at receiver end to listen to all of transmitted pulses. It transmits signals through air but its operation is not affected by sunlight or black materials. Its key benefit is that it has high range accuracy and reliable readings, making it a simple-to-use package. [3]. It will be used to accurately detect the fluid level in the drip bottle. To utilise it in the project, we link the GND pin to the Arduino's ground pin and the VCC pin to the 5V pin.

c) LDR (Light Dependent Resistor)

LDR is a light sensitive device in which the resistivity factor depends on the electromagnetic radiation received. It works on the principle that when light falls on the device, the resistance reduces, thus allowing current to pass through it. It is made from semiconducting materials. The resistance can be adjusted to make the circuit more or less light sensitive. It sends the resistivity factor value to the Arduino to perform other commands based on this value. LDR is used to detect the amount of light that passes through the fluid and sends the data to the arduino which compares it against an accepted range of resistivity factor values. Formation of bubbles will change the amount of light passing through the liquid because of reflection or refraction because of which the resistivity factor value that the sensor sends to the arduino may be out of the given range, hence detecting formation of bubbles in the drip.[4]

d) ESP8266 Wifi Module

The ESP8266 WiFi Module is a self-contained system on chip (SOC) with an integrated TCP/IP protocol stack. It is used to provide Wifi connection to Arduino Uno. It basically provides an interface between Arduino Uno and mobile or computer to share & receive data , results or commands . It acts as access points which provide access to Wifi networks to devices then further to a weird network. With the help of this module we can command Arduino Uno to perform certain tasks using mobile applications. The ESP8266 can host an application or outsource all WiFi networking capabilities to another application processor. Its main advantage is that it is not expensive, compatible with many environments and convenient to operate or give commands to Arduino Uno by user.[5] The capabilities of ESP8266 Wifi Module are used to set-up a communication network between Arduino and thingspeak website using the API key provided by the website.

e) ThingSpeak Website

ThingSpeak is an IOT analytics platform service. It first aggregates; collects the sensor data and sends it privately to the cloud, then it analyzes& visualizes that data using MATLAB and sends a trigger to the device to act based on the analysis of data collected. Wifi module i.e ESP8266 sends the data which is collected by devices like light sensor, ultrasonic sensor, etc to ThingsSpeak using popular IoT protocols on demand from third party sources.

Then the cloud analyzes and visualizes data in real time with help of MATLAB to discover patterns, relationships and trends in data. It combines data from multiple channels to build a more sophisticated analysis automatically according to schedule [6]. After analysis of data, it queues up the commands to execute based on new data and raw data , like sending alert messages to nurses when IV is less than a certain percentage, or sending alert messages if bubbles are formed in IV bag.

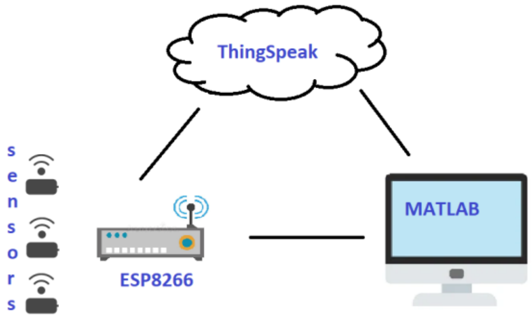

Figure 1: ThingSpeak diagram

3. Proposed Work

The system consists of Arduino Uno, HC SR-04 Ultrasonic Sensor, LDR, a light source and ESP8266-01 Wi-Fi module. The sensors are attached to the drip bottle which are controlled by the Arduino microcontroller, the collected data is transmitted to the thingspeak website through the wifi module where the data can be easily visualized. Then with the help of MATLAB it analyses the data collected from sensors. The android app retrieves this data from the cloud and notifies the hospital staff about formation of bubbles and the amount of fluid left in the drip. This is demonstrated by the diagram given below.

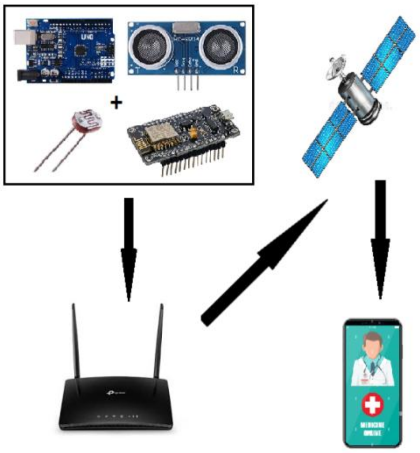

Figure 2: Workflow Diagram

a) Design and Working

The two objectives for the design of this system are:
(a) Measuring the level of the fluid in drip,
The HC-SR04 ultrasonic sensor is attached to the top of the drip bottle which is used to measure the level of the fluid. The level of the fluid is measured by using a simple equation:

$$l = height - d \quad (1)$$

where,
l is the length of the fluid present in the bottle.
height is the length of the bottle.
d is the measured distance from the ultrasonic sensor the the surface of the fluid present in the bottle.

Assuming the height =12 cm we get a table for level of IV.

Table 1: Level in drip w.r.t D from ultrasonic sensor

D(from ultrasonic sensor) (cm)	L (level of IV left in bottle) (cm)	Percentage shown in app (%)
12	0	0
11	1	8.3
10	2	16.6
9	3	24.9
8	4	33.2
7	5	41.2
6	6	49.8
5	7	58.1
4	8	66.4
3	9	74.7
2	10	83
1	11	91.3
0	12	100

When the level is 2cm (or d = 10 cm or percentage =16.6%) then the arduino sends a trigger to the app and the app displays the alert message for the nurse to be alert for this patient.

b) Detection of bubbles in the fluid

LDR is attached to the bottom of the drip bottle along with a light source at the top of the bottle besides the ultrasonic sensor. An initial range of resistivity factors are read by the LDR when clean fluid (i.e. without any bubbles) is filled in the bottle, if any reading is taken afterwards for the fluid falls out of the accepted range, we can conclude that there may be formation of bubbles in the drip bottle . Due to bubble formation, the amount of light reaching the LDR changes because of reflection and refraction hence changing the measured resistivity factor for the respective fluid.

LDR work is based on the principle of photoconductivity. When lights fall on the sensor, photons in light excite the electron in the valence bond and are excited to the conduction band. More the electrons are excited , the more charge carriers are created.

$$\sigma \propto \frac{1}{\rho}$$

$$\sigma = conductivity$$

$$\rho = resitivity$$

This process results in more current in the circuit, which increases the conductivity of the material and hence it can be said that resistance of the device is decreased.(as resistance is directly proportional to resistivity and resistivity is inversely proportional to conductivity as shown in above formula)

LDR is a light dependent resistor (resistance is variable with light sensed by the sensor). But arduino measures voltage , so to convert variable resistance to voltage we connect a resistor in series with LDR. So, when resistance drops with light, which causes current to increase, and then voltage across the resistor which we attached with LDR increases.

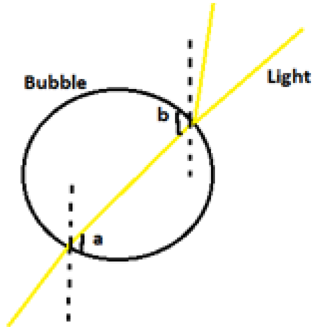

Figure 3: Refraction of light in bubble

Now, when light passes from the bubble it gets refracted as shown in fig3. Light emerging from get deviated from path and some light rays do not reach the LDR sensor as shown below in fig4.

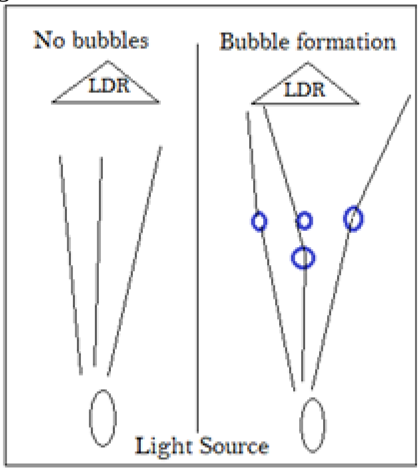

Figure 4: Light refraction in no bubble & bubble formation

As shown in fig4 than in case of bubble formation less light falls on the sensor area, which causes less light to be absorbed by the LDR sensor and less electrons are excited, which in result decreases the conductivity of material. As resistivity & resistance are directly proportional to conductivity they increase with decrease of conductivity. Hence resistance increases which decreases light absorbed by the LDR sensor.

Therefore we can say that if bubble formation is there then illumination (light absorb by LDR sensor)will be less & resistance will be higher as compared to resistance when there is no bubble formation and all the light emitted from the light source in the bottom of drip is absorbed by the LDR sensor. If the sensor absorbs more light its resistance will be decreased drastically.

More bubbles forming then less light will be absorbed by the sensor as more light will be scattered by bubbles, Hence resistance will be increased exponentially.

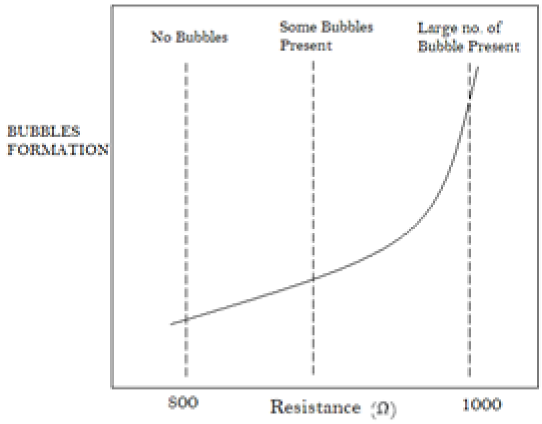

Figure 5: Resistance Vs Bubble formation graph

When there is no bubbles formation in liquid then resistance value is 800 and it increases non-linearly with bubbles formation. LDR are less sensitive than normal photodiodes, this leverages us in neglecting the resistance change due to light coming from the patient room and interfering with the detection of bubbles formation. Hence gives the accurate measurement of bubble formation in liquid.

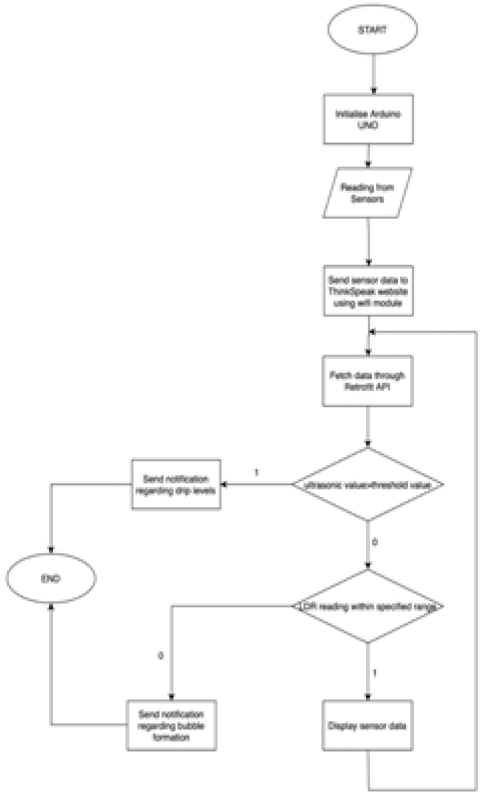

Figure 6: Architectural Diagram

Arduino Uno controls the sensors, process the collected data and transmit it to thingspeak website using the API key provided by the website with the help of a wifi connection through ESP8266 Wifi Module. The system's circuit diagram is shown below.

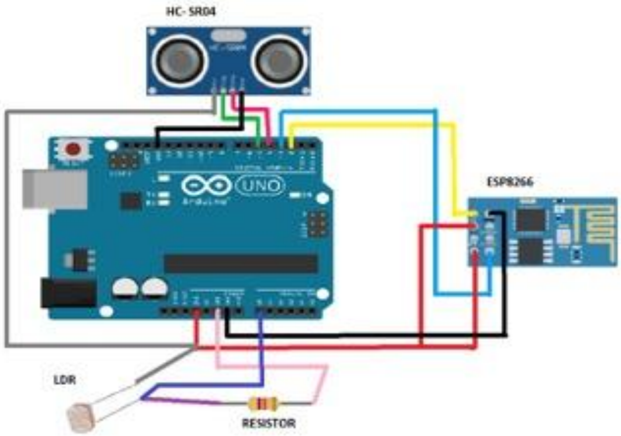

Figure 7: Circuit Diagram

As shown in the diagram we attach D4 pin of Arduino to Echo pin of HC-SR04 and D5 pin of Arduino to Trig pin of HC-SR04 for basic sensor function of sensor. Also we connect the LDR one end to resistor & A0 input pin of Arduino and another end to 5V powerpin of Arduino. Resistor free end is now attached to the GND pin of the Arduino.

c) Web and Mobile Applications

All the data from sensors is accessed using an open-source platform, ThingSpeak. It allows us to visualize data by helping us fetch it through an API on an app. One needs to register and login to see the patient's details. Under new activity, we can see the drip level and know about any bubble formations, if any, which is being fetched through a retrofit API.

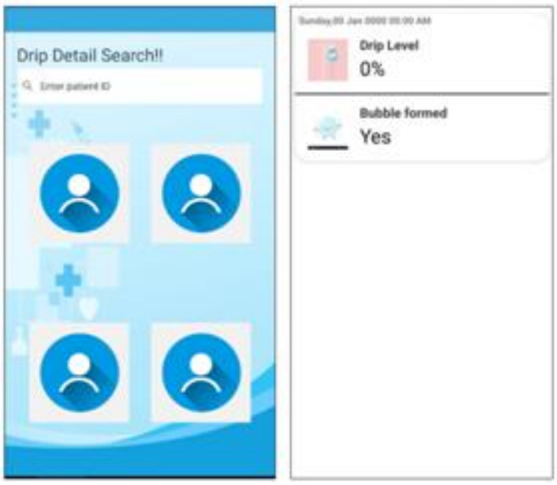

Figure 8: UI of App

4. Our project pictures

We have also brought our idea into reality. There are some attached images of how a smart IoT based IV drip will work and look like in real life, when used by nurses on patients in hospitals.

Figure 9: Smart IV drip image1

Figure 10: Smart IV drip image2

5. Conclusion

This study proposes an IoT-based monitoring and control platform for IV infusion setup. The suggested work decreases the amount of time and effort required to monitor the infusion setup and allows for wireless monitoring. It helps in ensuring there is zero margin of error as improper administration of drip can lead to many problems. It also improves clinical efficiency, safety and patient experience in hospitals and makes home care possible for many patients. The use of an ultrasonic sensor simplifies and expedites system implementation because it eliminates the need to calibrate the system for different fluids. LDR is used to detect bubble formation of the fluid which eliminates the risk of arterial air embolism which can cause heart attacks, stroke or respiratory failure. This system may be quickly installed on the stand where the drip bottle is hung, making replacing the bottle simple without having to bother about all the gear.

References

[1] https://www.arduino.cc/en/pmwiki.php?n=Main/arduinoBoardUno (Internet source)
[2] https://docs.arduino.cc/hardware/uno-rev3 (Internet Source)
[3] F. Noor, M. Swaied, M. AlMesned and N. AlMuzini, "A Method to Detect Object's Width with Ultrasonic Sensor," *2018 International Conference on Computing, Electronics & Communications Engineering (iCCECE)*.
[4] S. N. Ibrahim, M. S. L. Hakim, A. L. Asnawi and N. A. Malik, "Automated Water Tank Filtration System Using LDR Sensor," *2016 International Conference on Computer and Communication Engineering (ICCCE)*.
[5] https://www.robot-domestici.it/joomla/home/prodotti-al-prezzo-di-costo/wireless/wifi/wifi-module-esp8266-4mb/sparkfun (Internet Source) https://thingspeak.com/pages/learn_more (internet source)
[7] Sanjay.B, Sanju Vikasini.R.M, " IOT Based Drips Monitoring at Hospitals" *2020 International Research Journal of Engineering and Technology (IRJET) Volume 07, Issue 04 (April 2020).*
[8] M.Arfan, M. Srinivasan, A. G. Baragur and V. Naveen, "Design and Development of IOT enabled IV infusion rate monitoring and control device for precision care and portability," 2020 4th International Conference on Electronics, Communication and Aerospace Technology (ICECA)
[9] Amey More , Darshan Bhor , Mihir Tilak , Dr. Gajanan Nagare, "IoT based Smart Saline Bottle for Healthcare", *2021 International Research Journal of Engineering and Technology (IRJET)Volume 10, Issue 06 (June 2021).*
[10] S. Jiang and Y. He, "A low power circuit for medical drip infusion monitoring system," *2020 IEEE International Conference on Smart Internet of Things (SmartIoT).*
[11] A. W. Setiawan, N. Yenas and D. Welsan, "Design and Realization of Low-Cost Wireless Remote Infusion Monitoring System," *2018 International Seminar on Application for Technology of Information and Communication*
[12] N. Giaquinto, M. Scarpetta, M. A. Ragolia and P. Pappalardi, "Real-time drip infusion monitoring through a computer vision system," *2020 IEEE International Symposium on Medical Measurements and Applications (MeMeA).*