Design and Development of an Automated Electronic System for Intravenous Infusion Control, Monitoring and Alerting

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ABSTRACT

Intravenous simply means "within a vein." People of all ages who are ill, hurt, dehydrated, or going through surgery use it. Compared to conventional manual techniques, automated IV infusion systems may provide improved accuracy, consistency, efficiency, flexibility, and monitoring increase patient safety, and raise the standard of care delivered by medical professionals. The project's objective was to design and implement a fully automated low-cost user-friendly portable embedded-based system for monitoring, ceasing, and alerting intravenous infusion. This can be installed in hospitals, clinics, medical offices, ambulatory surgical centers, dialysis centers, nursing homes, and mental health and addiction treatment centers to monitor, cease and alert IV status to medical assistants. Successful design and implementation of an automated system that controls the intravenous infusion, stop the infusion when there's no fluid inside, sends an alert to the smart device in the nursing room, and continuously updates the intravenous infusion status. Arduino Uno was considered the heart of the device, as it controls all the functions of the device. For connecting the device to the cloud, the ESP826601 WiFi module was used. Blynk was the IoT platform used to display the status of IV infusions. User can enter their username and password using a 4x4 matrix keypad and displays the details via a 16x2 LCD. Based on that, the system was expected to validate the entered user credentials and BMI details to automatically stop the IV infusion and alert medical professionals by monitoring the IV drip infusion. The system's design and development increased patient safety while decreasing risk elements during infusion. The proposed system can be used to monitor the drip infusion of several patients from the nurse station.

Keywords: Intravenous infusion therapy, Arduino UNO, ESP8266.

1 Introduction

Intravenous (IV) therapy is a method used to provide fluids, medications, and nutrients to a patient quickly and in an effective manner [1]. This procedure allows water, medicine, blood, or nutrients to enter the body more quickly through the circulatory system. IV infusion therapy is most commonly used during operative and postoperative procedures to deliver drugs straight into the patient's bloodstream and to transfuse blood or some of its constituents [2]. Furthermore, it is used in patients with gastrointestinal system disorders, to treat dehydration, to correct electrolyte imbalances, and so on.

There are plenty of devices that are available in the market which help in the monitoring of the IV drip such as DRIPO – Smart Infusion Monitor, CLARITY – IV Alert Infusion Rate Monitor, etc. Both products have some advanced features like drip control, the status of the IV can be monitored wirelessly, a backup power of more than 10 hours, and so on. But a major feature is still missing from the system; that is the system won't stop the drip once the drip is over.

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Figure 1: *Intravenous Infusion Set [3]*

Figure 1 shows the intravenous infusion. The proposed system has an Arduino based microcontroller which is used to control the entire functions of the device. The device communicates with the cloud with the help of ESP8266-01. An IoT platform called Blynk is used to display the IV status of the patient. 16x2 LCD display which is used to enter the username and password of the healthcare professional which is required to operate the system. It is also used to display the height, weight and age of the patient which is used to calculate the body mass index (BMI). A 4x4 matrix keypad is given to enter the username, password, and height, weight and age of the patient. IR transmitter and IR receiver LEDs are used to monitor the IV drip. Relay unit is used to control the actuator. When the linear actuator turns on, it ceases the flow of IV drip.

Even though the existing IV infusion device is a simple system, it has many disadvantages. The main drawback is that it requires continuous monitoring of healthcare professionals. It seems to work only during normal days, but during busy days, it's difficult for them to monitor the IV drip status on time. Along with this, it becomes difficult for the nurse to manually stop the IV drip on time. This happens due to the absence of an alerting system in the existing IV infusion system. Another major problem with the existing system is that it requires excellent knowledge and experience to properly monitor the IV drip and adjust the flow rate, which is possessed only by medical professionals.

Improper monitoring of IV drip can cause some adverse events like reverse blood backflow, drug overdose, and so on. Many existing devices in the market can monitor the IV flow and can regulate the flow of IV fluid accurately, like infusion pumps. But such devices are expensive, heavy, and not portable.

Even though IV drip is a safe, affordable, and effective technique, its improper usage can result in a number of problems. As a result, the IV fluid infusion should be administered with utmost caution.

Only by addressing the issues that arise during the use of IV drips, minimizing complications and enhancing accuracy, can patients receive the essential treatment. As a result, there is a need for next-generation IV drip sets that can not only monitor but also halt the drip rate as needed.

2 Literature Review

As a framework for connection for a shear beam load-cell sensor and an RFID/NFC reader, a 6502-based embedded controller was used. The load cell turned the tension from the drip bag into a minor electrical signal. The improved electrical signal was received by a 16-bit analog to digital converter. Finally, the tension was converted to a two-byte digital weight. The weight data and data from the RFID/NFC ID were combined into a data packet and sent over the User Datagram Protocol (UDP) to an IV infusion monitoring system data collector module [4].

IV therapy was a typical treatment procedure that was utilized to enhance electrolyte balances inside the body, regulate drugs, or transfuse blood or fluids. The proposed technique eradicates the possibility of a heart attack from an air embolism as well as the issues associated with IV medication. Chemotherapy. In particular, it should be administered effectively and regularly [5].

Traditional procedures require medical professionals or nurses to be physically available to inspect on condition of the patient and to cease the IV infusion to avoid blood back-flow into IV tubing. The current process was designed to stop the IV infusion automatically when it was completed and inform the medical professionals via an app that also contains the patient's primary information. This minimized the requirement for frequent human intervention. The project will be defined and developed an ontology-based cyber-physical system architecture. It was capable of monitoring the patient's health conditions autonomously and securely with less labor [6].

A microcontroller based on Arduino was used for managing drop counters, discover tube blockages, and checking drip bag clearing. The mentioned monitoring functions were carried out by using optical sensors and low-power laser diodes in that system. Wireless data transferred to users' mobile devices through the Blynk IoT platform as well as programs was used to remotely monitor the rate of flow (in drops per minute) as well as infusion-interrupt difficulties. In the study, there was no distinction found between manual and automatic counting measurements. Additionally, the device may alert users of an unfilled bottle or a blockage in the line. According to the findings of the study, the prototype developed could be enhanced (in terms of design and performance) and tested for efficiency as well as uniformity in real clinical settings [7].

A real-time tracking of the infusion process was made possible by an IV infusion system used for observing and alerting that relied on wireless technology. A signal is triggered by the system to raise an alarm either at the end or when the infusion is interrupted, which reduces the difficulties of clinical IV infusion while enhancing security and efficiency. The detection of the flow of IV fluid signal was made possible by the use of signal processing technology and a photoelectric sensor in that system. A Single Chip Microcomputer (SCM), as well as digital screen technology, were also used for quantifying, exhibiting, and overseeing the volume and speed of the liquid, in addition to alerting if there is an absence of fluid or an obstruction. Using wireless communication technology, the nurse station screens the status of the infusion process of every ward in real time [8].

After many studies and research, it was made necessary to monitor the flow of IV infusion and should be delivered in a controlled manner. A system has been proposed which is controlled by microcontroller called ATMEGE128L, uses ZigBee for communication purposes with the help of CC2420 chip and monitors the IV infusion with the help of IR sensors [9].

IV therapy is one of the commonly used methods of delivering medicines to the patients. But it has some drawbacks. One of such is blood flowing back into the IV tube. To eliminate such issues, hospitals nowadays use cuff like devices which works when the backflow of blood occurs. It is mandatory to properly monitor the flow of medicine, but it is not always possible. For avoiding such problems, a "Smart IV Drip" prototype is proposed [10].

A case was filed in the year 2007 in Oregon about an old-aged woman died of heart attack after being hospitalized with symptoms like nausea, moderate hypertension etc. The tests conducted after her death revealed that she died due to incorrect dosage of IV infusion, which is the result of improper monitoring. [11].

Current artificial monitoring methods place a burden on patients, family members, and medical staff. Several principles are introduced to address the shortcomings of the current system. An Arduino-based microcontroller was used to test the drip bag. To detect optical drops, an infrared sensor was used. Wireless

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data transfer was used to track the infusion rate in real-time. To prevent blood backflow, an IV monitoring system based on load cells was used. The death of a 77-year-old woman highlights the importance of IV monitoring. Therefore, proper attention is needed for the medical procedure.

3 Methodology

The main aim of this project was to design and implement a fully automated low-cost user-friendly portable embedded based system for monitoring, ceasing, and alerting of IV infusion. This can be installed in hospitals, clinics, medical offices, ambulatory surgical centers, dialysis centers, nursing homes, mental health, and addiction treatment centers to monitor, cease and alert IV status to medical assistants. The main features of this device are:

- The product monitors the flow of IV infusion.
- To ensure security, it has a username and password. It is accessible to the medical assistant.
- Outside the patient's room, a system consisting of 3 LEDs is kept which helps in monitoring the IV status of the patient.
- To monitor the IV status of the patient and stop the infusion in case of emergency, a web-based application is used.
- These 3 LEDs are used to display the patient's IV infusion status.
- The green LED indicates the flow of IV infusion.
- The end of IV infusion was indicated by the red LED.
- A yellow LED indicates that there are no patients available for IV therapy.
- In case of an emergency, a switch is used to stop the infusion.
- The medical assistant has access the emergency switch.
- Using a linear actuator, the infusion is stopped.
- An alerting signal will be received the nursing station to indicate the end of IV infusion.

3.1 Proposed System

Healthcare experts have to type in their corresponding user- names and password to use the device. The device is controlled by an Arduino based microcontroller. The system communicates with the cloud through ESP8266-01. A 16x2 LCD and a 4x4 matrix keyboard are provided to display the entered contents and to enter the username and password respectively. The user has to enter the patient's name, height, weight, and age to calculate the BMI of the patient. If the calculated BMI is normal, then the IV drip starts to flow. The IR transmitter and receiver LED are used to observe the flow of the drip. The broken line suggests the passage through which the iv line is kept. The output from the IR receiver is fed to the Arduino board, which controls the whole working of the system. The Arduino board continuously monitors and updates the status of the IV drip on the smart device. Once the IV drip is finished, it activates the relay which turns the linear actuator thereby stopping any further flow of the IV drip. Along with this, an alert is sent to the nursing station.

Detailed Block Diagram of Proposed System

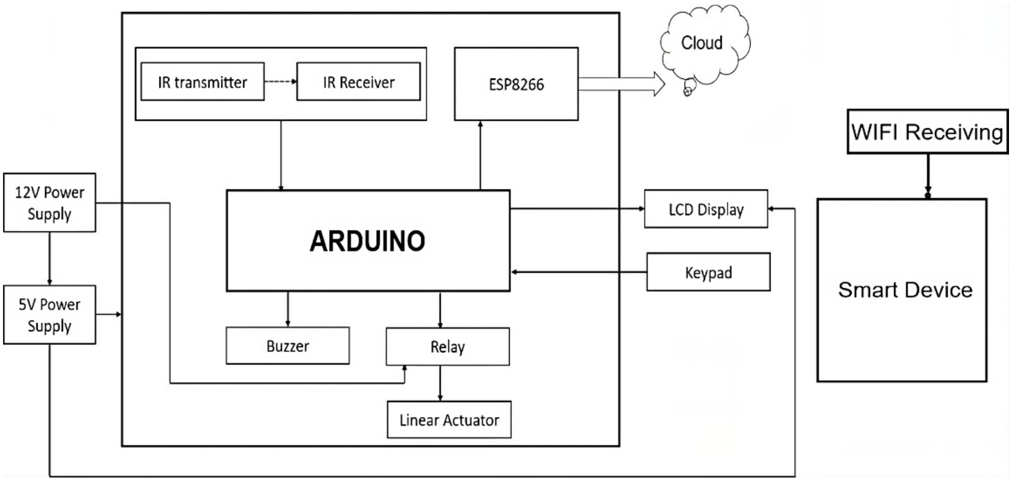

Figure 2: *Block Diagram*

Figure 2 shows the block diagram of the proposed system. The proposed system has two sections: The transmitting and receiving unit.

Transmitting Unit: Transmitting unit consists of IR transmitter LED which is used for emitting IR rays, IR receiver LED is used for detecting IR rays, Arduino Uno can be considered as the heart of the system as it controls all the functions of the system, ESP8266 WiFi module is used for communication of the system with cloud, 16x2 LCD is used to display the credentials entered by the healthcare professionals, 4x4 matrix keyboard is used to enter the credentials entered by the healthcare professionals, Relay unit controls the linear actuator and Linear actuator ceases the flow of IV drip.

Receiving Unit: The receiving unit is a smart device with an IoT platform called Blynk IoT. The User interface has three LEDs with which the status of IV drip can be monitored.

3.1.1 Process Flow

STEP 1: Power is supplied from a 12 V adapter and the device is turned ON.

STEP 2: The device shows an alert message if there is any malfunction.

STEP 3: Nurse inputs her credentials, i.e., username and password. If the entered credentials are incorrect, then the device shows an alert message.

STEP 4: The nurse inputs the name of the drug prescribed by the doctor. If the drug is not available, the nurse informs the doctor and requests for an alternative drug to be given to the patient.

STEP 5: The nurse enters the patient's name, age, height, and weight to calculate the BMI of the patient.

STEP 6: The device sends the request to the cloud for the corresponding patient's medical history.

STEP 7: The device calculates the BMI of the patient and checks whether the patient has any allergic reaction to the corresponding drug.

STEP 8: After evaluating both cases, the IV drip starts when both cases are satisfied. If not, an error message will be displayed.

STEP 9: Doctors and nurse can monitor the IV drip status on their smart device with the help of a web application called Adafruit.

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STEP 10: Doctor and nurse get an alert when the IV drip is over.

STEP 11: The nurse can stop the IV drip via a web application in case of an emergency.

3.1.2 Algorithm

Step 1: Start

Step 2: Input USERNAME and PASSWORD.

Step 3: If false, Goto step 2.

Step 4: If true; input patient ID, age, height and weight.

Step 5: Calculate BMI = weight / ((height / 100.0) * (height / 100.0)).

Step 6: Check whether BMI ≥ 18.5 and BMI ≤ 25.

Step 7: If false; display ”Drug cannot be given”.

Step 8: If true, set data from Analog pin A0 to sensorValue.

Step 9: If sensorValue ≥ withIV - 20 and sensorValue ≤ withIV + 20 is true, go to step 10.

Step 10: Enable virtual pin V0 HIGH.

Step 11: If false, go to step 12.

Step 12: If sensorValue ≥ withoutIV - 5 and sensorValue ≤ withoutIV + 5 is true, go to step 13.

Step 13: Enable virtual pin V1 HIGH, enable digital pin D11 high for 5 secs and enable D10 HIGH for 2secs.

Step 14: If false, go to step 15.

Step 15: If sensorValue ≥ noTUBE - 5 and sensorValue ≤ noTUBE + 5 is true, go to step 16.

Step 16: Enable virtual pin V2 HIGH.

Step 17: If sensorValue == 0 go to step 18.

Step 18: Display “Technical error”.

Step 19: Stop.

3.1.3 Flowchart

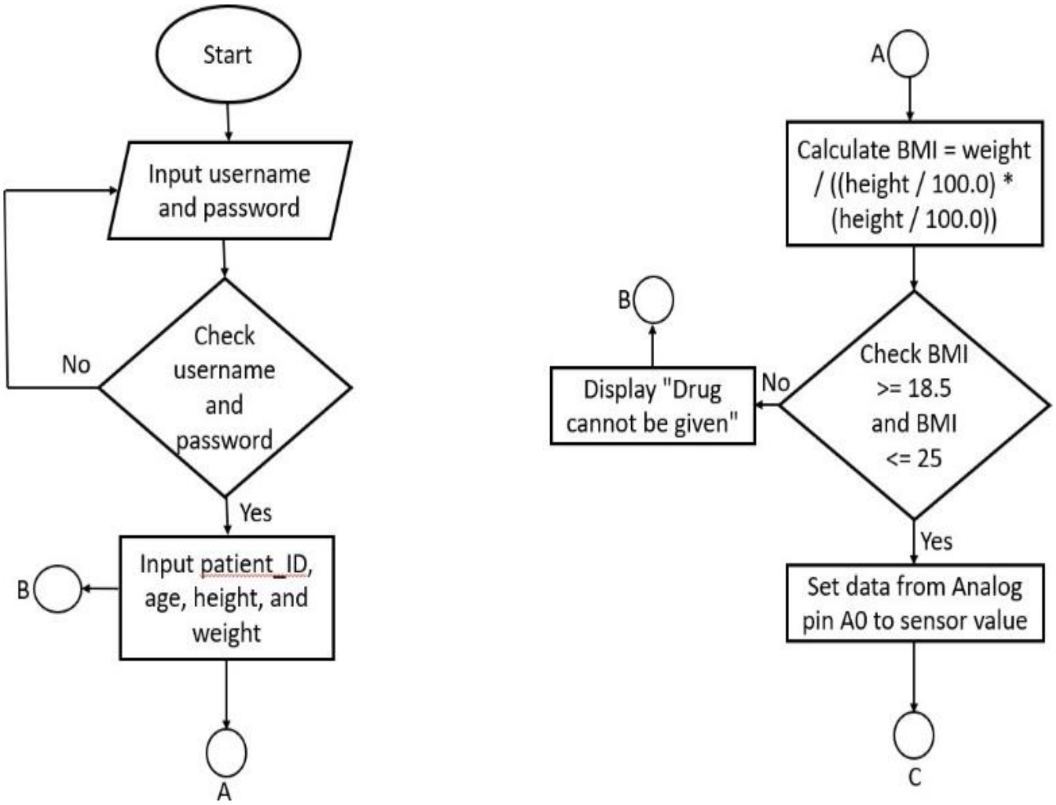

Figure 3: *Flowchart*

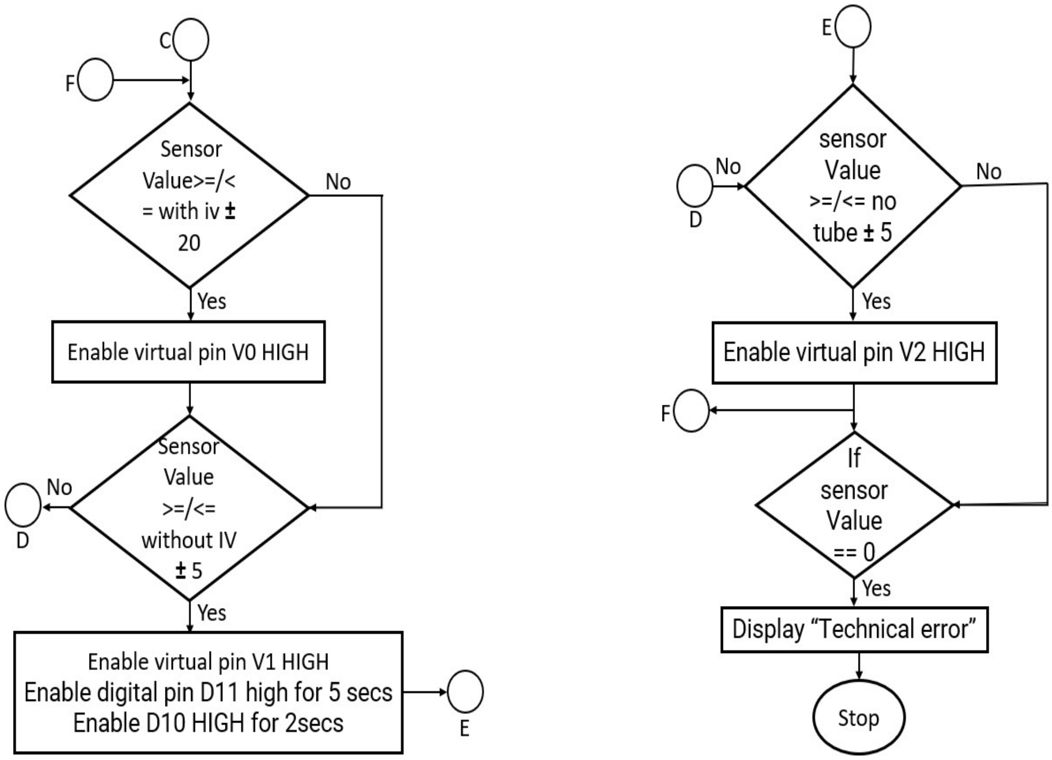

Figure 3: *Flowchart*

Figure 3 shows the flowchart. The entire working procedure of the product is presented.

3.1.4 Circuit Diagram

The circuit diagram of proposed device is given below.

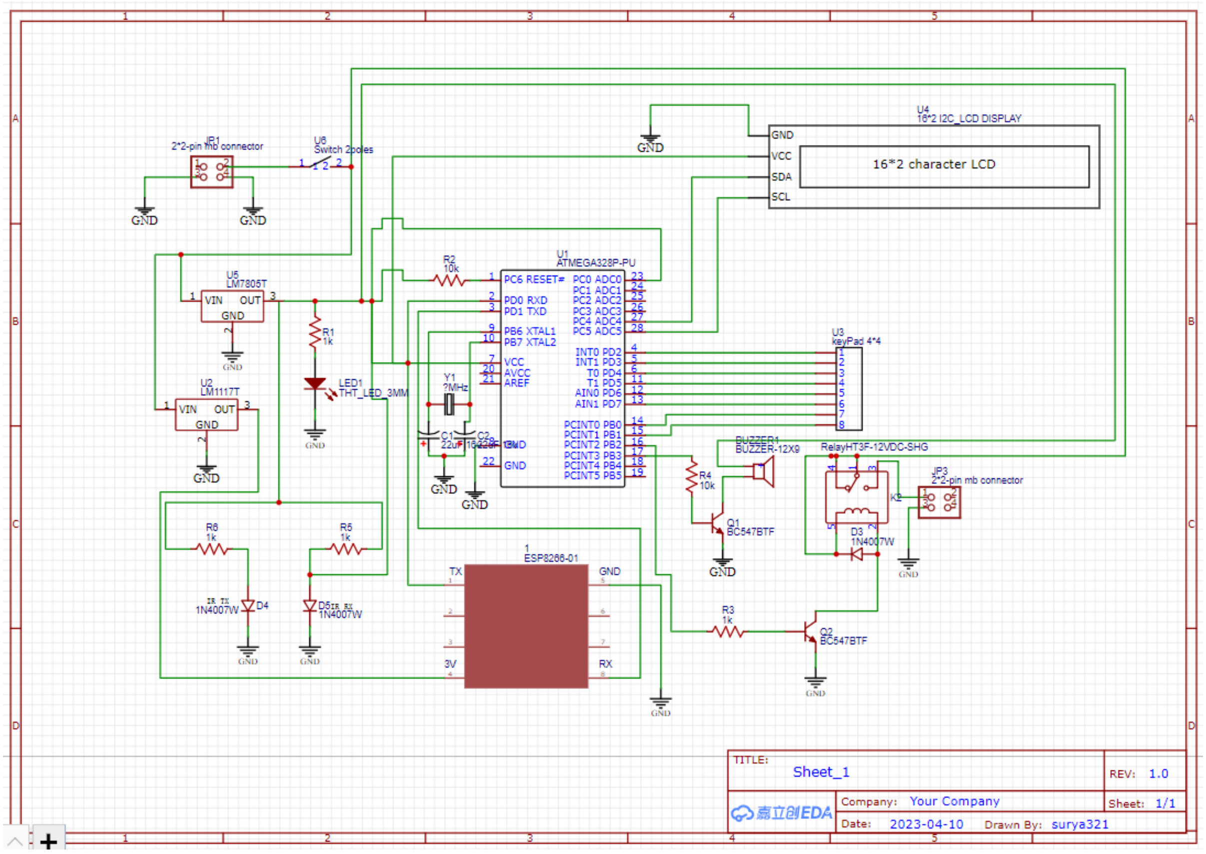

Figure 4: *Circuit Diagram*

Figure 4 shows the Circuit Diagram of the proposed system.

The system was provided with an external power supply made of 12-0-12 center-tapped transformer, 1000 uF 53 V capacitor and 2 A diode which provides an output voltage of 12 V 2 A. This was supplied to a 7805 voltage regulator chip which gives an output of 5 V 1.5 A. This was supplied to the IV monitoring system which consists of an IR transmitter and IR receiver. 16x2 LCD and 4x4 keypad matrix keypad were connected to enter the username and password. The output from the receiver LED is sent to the A0 pin of the Arduino Uno. The output from the Arduino Uno was connected to BC547 through a 100 ohm resistor. 100 ohm is so set in order to restrict the input received at the base. The collector is linked to a 12 V relay, while the emitter is grounded. Given that the relay has a coil-like construction and may create reverse current, a 1 A diode is attached across the relay. This diode is positioned to prevent it. Finally, an actuator is utilised to stop the intravenous drip. It was connected to a relay. A piezo electric buzzer was also connected to the Arduino board for alerting purpose.

3.1.5 Simulation

After simulation, the following output was observed.

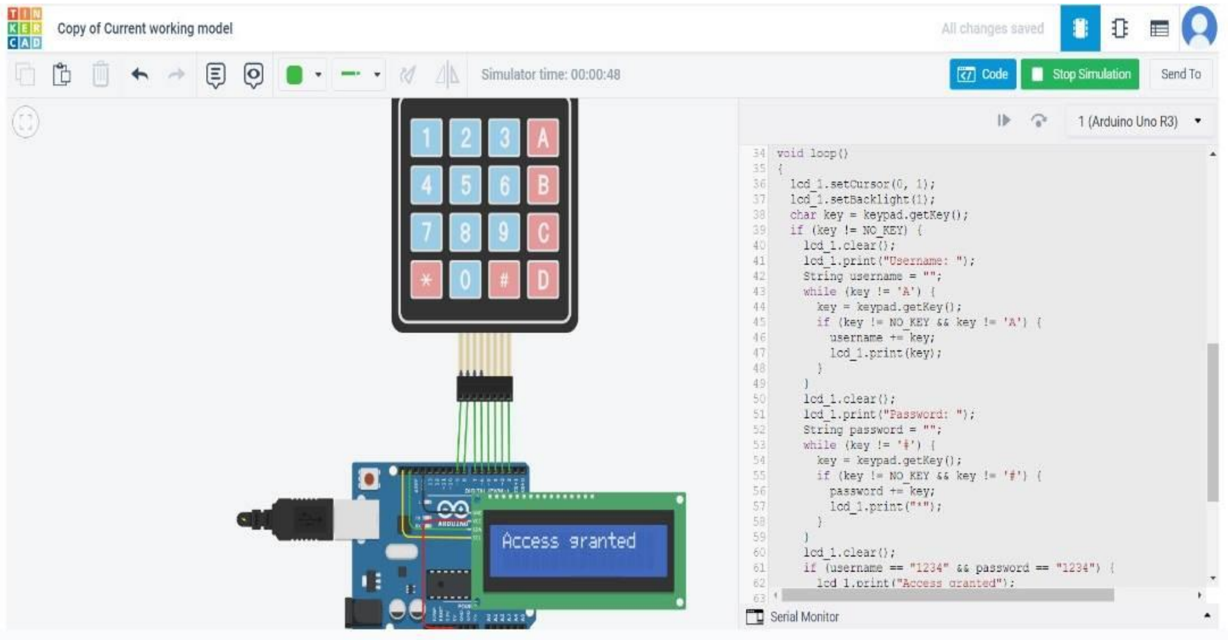

Figure 5: *Simulation*

Tinkercad was used to get the simulated view of the system. Figure 5 shows the simulated view of the proposed system.

3.1.6 Hardware Implementation

Successfully implemented the proposed system on bread- board and made the prototype fully functional.

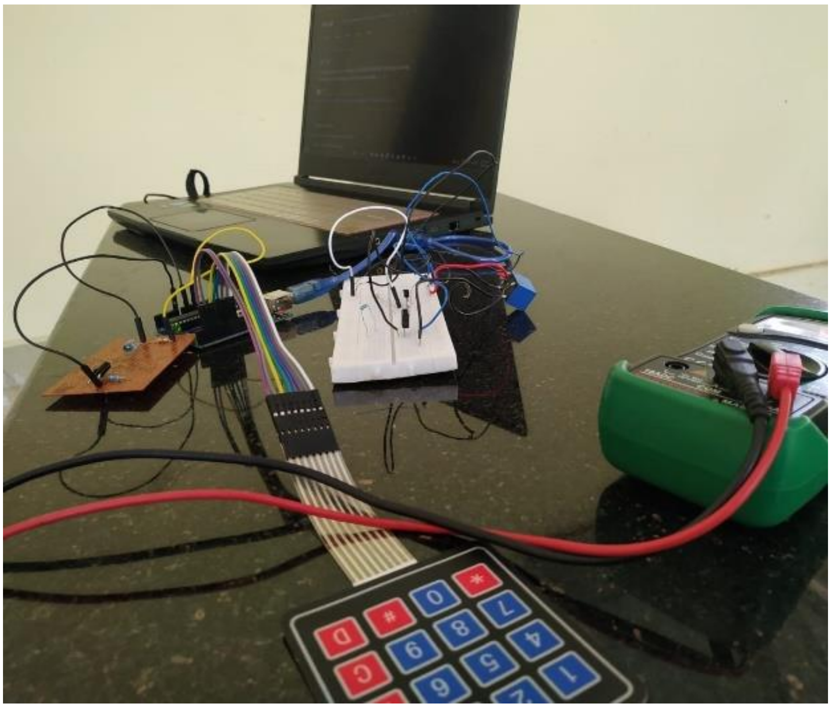

Figure 6: *Breadboard implementation of the hardware*

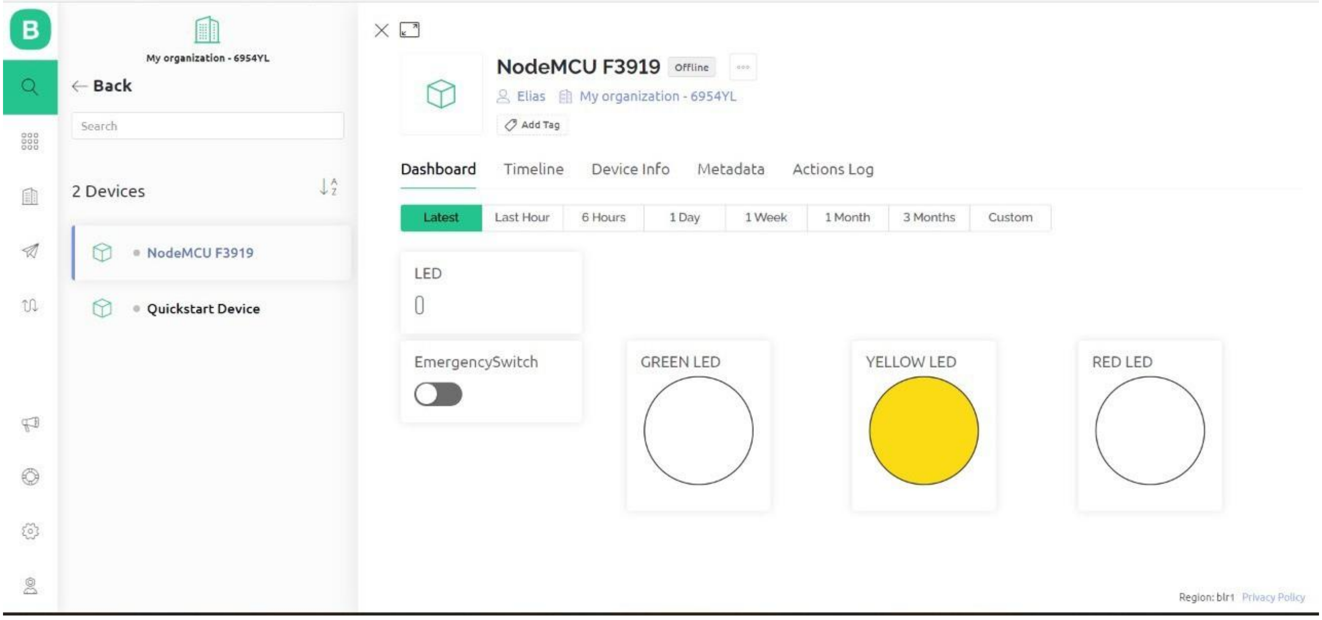

Figure 7: *Set up for Blynk Application*

4 Discussion

In the current market, there are various products available to tackle with the problems in the old IV infusion set such as no monitoring system, less accurate, chance of patient experiencing air embolism, etc. Some of them are DRIPO, Clarity IV, etc. These products eliminated many drawbacks of the existing IV infusion set. They also made job of the medical professionals easier by allowing them to monitor and control the infusion using electronic components. This literally eliminated the need for frequent monitoring and controlling of the IV infusion. But these products have a drawback which is the lack of a system which ceases the flow of IV when it's over. The proposed device has a system equipped for ceasing the flow of fluid once it is over. The proposed system also considers a patient's BMI to check whether the particular drug can be given to that individual or not.

5 Conclusion

IV therapy is a medical procedure in which fluids, medications, and nutrients are injected directly into a patient's vein. This procedure expedites the entry of water, medicine, blood, or nutrients into the body via the circulatory system. The most common type of IV infusion system found in hospitals around the world is non-automated IV infusion system. Even though the current IV infusion device is a simple system, it has numerous drawbacks. The main disadvantage is that it necessitates constant monitoring of healthcare professionals. It appears to work only on normal days, but on busy days, they struggle to keep track of the IV drip status. This makes it difficult for the nurse to manually stop the IV drip on time. Another major issue with the current system is that it requires exceptional knowledge and experience to properly monitor the IV drip and adjust the flow rate, which is only available to medical professionals. Improper IV drip monitoring can result in adverse events such as reverse blood back flow, drug overdose, and so on.

This paper describes a fully automated low-cost user-friendly portable embedded-based system for IV infusion monitoring, cessation, and alerting. This can be installed in hospitals, clinics, medical offices, ambulatory surgical centres, dialysis centres, nursing homes, mental health, and addiction treatment centres. This system will reduce the hectic work pressure on the healthcare professionals.

6 Publisher's Note

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