Design and Development of saline flow rate regulatory system

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Abstract— **Intravenous (IV) therapy is a medical procedure in which the liquid substances are directly entered into the vein through an Intravenous tube and needle is inserted into the patients' vein. Now a days , many automatic health monitoring devices are developed to ensure the patients safety and to reduce the stress of the doctors and patient assistants. Whenever a saline is fed to any patient, the patient needs to be continuously administered by a nurse. Due to lack of caring, many problems will arise such as backflow of blood through the tube. To overcome this situation, saline flow rate regulatory system has been developed. The proposed system consists of sensors for monitoring the critical level of the saline in the saline bottle. Whenever the level of the saline reaches to the pre-set level, then the nurses and doctors will be alerted through the buzzer and an alert message will be sent through the use of internet to the concerned nurses and doctors and automatically turned off the flow of a liquid from the IV tube by using the solenoid valves. Here, efficient saline flow rate regulatory system has been explained with two cases. DC motor and necessary accessories are utilized and tested for case I and Stepper motor and necessary accessories are utilized and tested for case II.**

Index Terms: **Arduino Uno, DC motor, IoT, Sensors, Stepper motor.**

1.INTRODUCTION

Saline was believed to have originated during the Indian Blue Cholera that swept across Europe in 1831. William Brooke O'Shaughnessy, proposed in an article to medical journal The Lancet to inject cholera patients with highly oxygenated salts. His proposal was soon accepted by the physician Thomas Latta in treating cholera patients to beneficial effect. The need for the hour is to automate everything. Human life has become far more dependent on electronic devices. In its various electronic gadgets, the world of today requires sophisticated control. Hence even the Health care requirements are rising rapidly as the world's population continues to grow. The rapid advancement of sensors and microcontrollers has observed tremendous success in medical technology. For the benefit of improving medical services, numerous technological innovation designs are taken. Automation in day to day lives helps increase the efficiency of our work and saves time. The basic objective of the indicator of saline level is to alleviate human lives. When the patient's body is dehydrated, saline should be fed. Constant monitoring of the bottle's saline level is necessary. If the saline in the bottle is consumed completely, then the difference between the blood pressure of the patient and the empty saline bottle causes an outward rush of blood into the saline. This situation may pose a serious threat to the well-being of the patient .The amount of the patient's Normal Saline intake depends entirely on the patient's physiological condition. In case of normal adult it lies between 1.5 to 3 liters per day. The intake of oxygen flow is 2-4 litres/min. Nurses and patient attenders usually monitor the flow level in hospitals. Unfortunately, due to their busy schedule, the observer may forget to change the flow of saline in the bottle at the right time. This can lead to patients having several problems, such as backflow of blood, blood loss etc. The existing flow monitoring system for nurses is very time-consuming and inconvenient.

Fig. 1 - Blood back flow in intravenous tube

The lack of nurses with sufficient skill in hospitals and their heavy duty become a social problem in the modern world. We must develop low cost health monitoring systems available to every hospital in the days to come. Figure 1.shows the blood back flow in intravenous tube.

In our work instead of varying the saline flow rate manually using screw clamp, we can control the saline flow rate automatically using mechanical device and Arduino.

Main objectives of this proposed system is

To provide greater accuracy than manual saline flow rate control system.

To send message to the doctor /nurses cell phone using IoT.

To provide a digital system to indicate the number of drops flow in the catheter.

To inform and automatically stop the flow after emptying of saline bottle.

To make the saline monitoring automatic and inform the doctor/nurse spontaneously for patient safety and easy access when required.

2. LITERATURE REVIEW

Sumet Umchid et al..[1] focused on a monitoring system for saline administration. The objective of this work is to design, develop and construct a saline monitoring system to help the medical staffs in order to notify them when the saline level is almost empty or below the setting value. The load cell is used to measure the weight of the saline. The signals from the load cell will be transferred to a microcontroller to convert saline weight to saline volume. The volume of the saline is displayed on the LCD screen of the developed system. B. Naga Malleswari et al [2] discussed on Smart saline level monitoring system using IOT. This framework comprises of different sensors and devices and interconnected by means of remote correspondence modules. The sensors data is sent and received from the nurse or doctor end using internet which was enabled in the Node MCU module-an open source IoT plat-form. Mohammed Shafi KP [3] focused on the development of a low cost automatic regulating the liquid flow rate system. Most of the times when a patient undergoes intravenous setup, they needs to be continuously monitored by the nurses. Due to the inattentiveness, carelessness and higher number of patient's, the saline in the bottle is entirely consumed. This may create crucial damage to patient and IV tube. After the bottle is sapped to its last drop, due to the pressure variation between the empty bottle and blood pressure, blood will rapidly rush in to the bottle. This situation may be handled by automatically controlling the intravenous tube. Sensor sense the level send the signal to servo motor to cease the flow through IV tube. S.Muthupandiyan et al [4] dealt on low cost automated fluid control device using smart phone for medical applications. The design and implementation of an automated liquid observation was analyzed. The PIC microcontroller platform has been used as control unit. Bluetooth module is used to control the drop per minute manually and by using an android phone. The designed flow sensor is hooked up to the drip chamber of the saline container to determine the saline flow rate as well as number of a drop of the saline. The obtained outputs from the sensor are continuously monitored with the certain command and if any mismatch is found. Dinesh Kumar J.R et al [5] discussed on a novel system design for intravenous infusion system monitoring for betterment of health monitoring system using ML-AI. Here, Scrupulous flow has to be retained so that risks of fore shortening the threshold level of patient's heart rate, blood pressure and oxygen level in blood level. For the change in threshold level of patient's body condition, saline flow has to be adjusted. The machine learning based algorithm is used to predict the more accurate changes on data which is obtained from patients so that the controller can act agile. MunemFarhan et al [6] focused on Design and Fabrication of automatic intravenous (IV) fluid feed system. They may forget to monitor it properly which may lead to severe problems for patient. This system will be helpful in this situations. Multiple medicines can be feed to the body through one system and one line. Here, one can easily set the time of feeding saline automatically by the system. This system can be controlled by Arduino Mega 2560, Two servo motors, solenoid valve, and Bluetooth module are used in this system. M.B. Disselkoen [7] discussed on the design of a sensing and regulating method to improve the control of gravity based intravenous (IV) therapy. Different techniques are available for the administration of IV fluids. The two main administration techniques are active and passive type. The active devices are expensive and deliver fluids at a high accuracy. Passive devices are configured by manually sets a flow adjusting tube clamping device, based on the flow rate. C.C Gavimath et al. [8] proposed an automatic saline monitoring system using a low cost indigenously developed sensor and GSM (Global system for mobile communication) modem. The 8051 microcontroller is used for providing necessary action. IR sensor is used to know the flow rate of the liquid in the saline bottle. The output obtained from the sensor is processed and the same is transmitted through GSM technology to a distant mobile cell for future actions. Neeraj Kulkarni et al [9] discussed the traditional strategies used for health care are getting obsolete because of increase in population. The automatic saline flow monitoring system which might be simply implemented in any hospital and may be easy for doctors similarly as nurses to monitor the saline be due a distance. The projected system got rid of continuous on sight watching of patient by nurses or doctors. Additionally monitoring of heartbeat or paralysis attack by using heartbeat sensor and mems sensor. M.Anand et al [10] discussed the devices which is used in medical field. Many devices are introduced a drastic change for monitoring the body measures like blood pressure, heart beat rate, diagnosis of heart attack symptoms. Health care monitoring system is becoming more valuable for these days. In this proposed system the intravenous fluid monitoring system automatically send a message to the nurse through GSM technology. The patent's pulse rate and the blood pressure is continuously monitored and displayed on the liquid crystal display (LCD).

3. EXPERIMENTAL SETUP

The effectiveness of this proposed system has been analyzed with two cases as follows

Case I : Using DC motor

In this proposed system, saline reaches the critical level which is sensed by IR sensors and this sensed output is sent to the Arduino UNO controller. It scans the database for retrieving the available information, then the buzzer starts ringing for alerting the nurses and doctors in the hospitals. A time limit will be set for ringing of the buzzer. An alert message is sent to the concerned nurses and doctors associated with the patient through the use of internet. If the nurse attends the patient, then she should stop the buzzer and reset the whole system. If the nurse fails to attend the patient within the set time limit, the reverse flow of the blood into the saline bottle should be stopped. For this purpose, a spring and DC motor arrangement will be made. A clamp is attached to the spring which has compression and stretching characteristics. This spring is activated depends on the motor input. The clamp will also move in forward and backward directions. Arduino UNO gives the instructions to the DC motor and as per the functioning of motor, the spring will be stretched and the clamp will move.

3.1 System Description

In this proposed system there are two IR Sensor used to transmit and receive the voltage level changes when intravenous fluid level is below prescribed limit. The system also consist of Arduino UNO micro-controller which will be programmed in order to send alarm buzzer to nurses and doctors to indicate the critical level of saline. The main components are IR sensors, Arduino UNO Microcontroller, DC Motor, Buzzer, Spring arrangement and power supply unit. IR sensor is used to sense the voltage level changes when the saline in the bottle reaches a critical level. It will be positioned at the critical level of the saline bottle that is near the neck of the bottle. To get the desired output the Arduino UNO micro-controller needs to be programmed. Here the Controller plays the major role in turning on the alarm buzzer . The DC motor is helpful in moving the spring forward and backward. Buzzer helps to notify the nurses, caretakers and doctors about the saline level. Spring is used to store mechanical energy and helps to stop the reverse flow of blood in the tube. The Power supply units consist of 5 V step down transformer and rectifier. Battery acts as a back-up source which will also provide 5V in case of power failure. Figure 2. shows the Mechanism for stopping reverse flow of blood using DC motor arrangement. Figure 3. shows connection diagram for Arduino UNO board with DC motor arrangements.

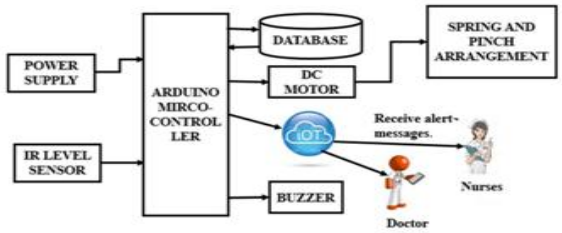

Fig. 2 - Mechanism for stopping reverse flow of flow of blood using DC motor arrangement

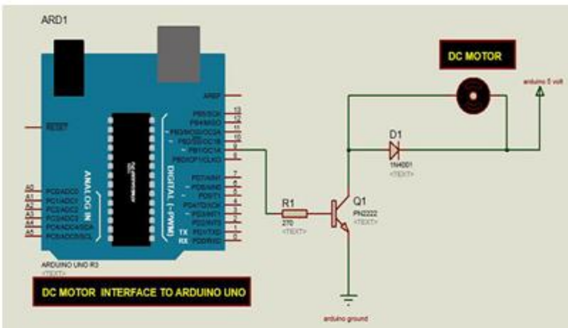

Fig. 3 - Connection diagram for Arduino board with DC motor arrangements

3.2 Arduino code

```
int motorPin = 9;
void setup() {
  pinMode(motorPin, OUTPUT);
  Serial.begin(9600);
  while (! Serial);
  Serial.println("Speed 0 to 255");
}
void loop() {
  if (Serial.available()) {
    int speed = Serial.parseInt();
    if (speed >= 0 && speed <= 255) {
      analogWrite(motorPin, speed);
    }
  }
}
```

Figure 4. shows the laboratory model for saline flow rate regulatory system with DC motor

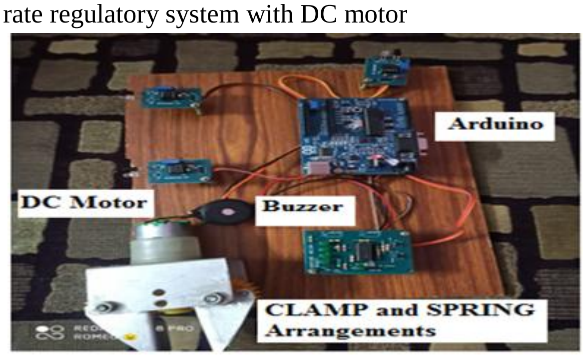

Fig. 4 - laboratory model for saline flow rate regulatory system with DC motor

Case II : Using Stepper motor

3.3 System description

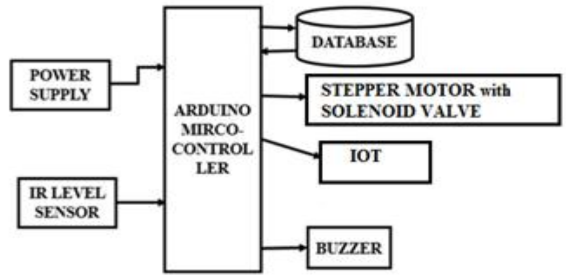

Fig. 5 - Mechanism for stopping reverse flow of flow of blood using Stepper motor arrangement

The system is based on digitalizing the flow of saline. Here, based on the number of drops that is required for the patient, the system is designed. There are two push buttons which may rotate the stepper motor clockwise or anti-clockwise direction. One button for increasing the number of drops and the other button for decreasing the number of drops. The arduino Uno is uploaded with the source code, if once the push button is operated, one drop per sec saline flows. If twice the push button is operated, the saline flows two drops per second. This continues up to 4 drops per second on operating the push buttons. If there may be any decrease in the flow of the saline, then the second button is operated. It is similar to operation of the clockwise push button. When operating the push buttons, the drops per second flow is displayed on the LCD. Once the push button is operated, the stepper motor rotates with the mechanical device, and releases or compresses the catheter tube. Once the saline bottle tends to become empty, the user can operate the push buttons clockwise for four times and stop the saline flow which will also stop the reverse flow of blood. This process is recorded and sent to the doctor or the nurse. This every process of the system is handled by the arduino uno, where the entire source code for interfacing all the necessary components is uploaded. In this way the saline flow rate is monitored and controlled digitally. Figure 5. shows the mechanism for stopping reverse flow of flow of blood using Stepper motor arrangement. Figure 6. Connection diagram for Arduino board with stepper motor arrangements.

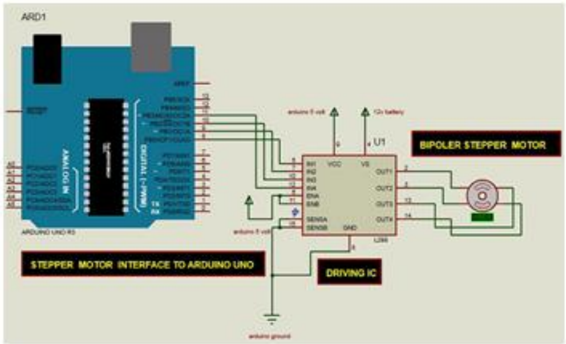

Fig. 6 - Connection diagram for Arduino board with Stepper motor arrangements

3.4 Arduino code

```
/* Stepper Motor Control */
#include <Stepper.h>
const int stepsPerRevolution = 90;
// change this to fit the number of steps per revolution
// for your motor
// initialize the stepper library on pins 8 through 11:
Stepper myStepper(stepsPerRevolution, 8, 9, 10, 11);
void setup() {
  // set the speed at 60 rpm:
  myStepper.setSpeed(5);
  // initialize the serial port:
  Serial.begin(9600);
}
void loop() {
  // step one revolution in one direction:
  Serial.println("clockwise");
  myStepper.step(stepsPerRevolution);
  delay(500);
  // step one revolution in the other direction:
  Serial.println("counterclockwise");
  myStepper.step(-stepsPerRevolution);
  delay(500);
}
```

Figure 7. shows the laboratory model for saline flow rate regulatory system with stepper motor.

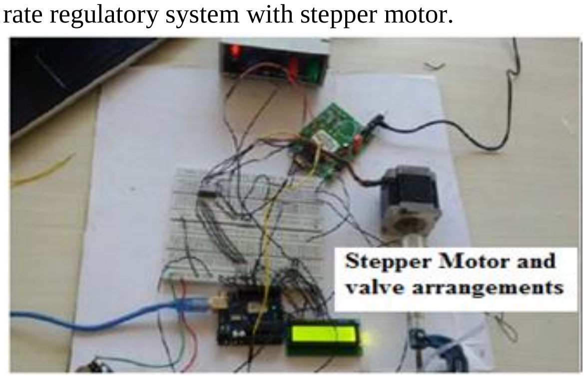

Fig. 7 - Laboratory model for Saline flow rate regulatory system with stepper motor

4. CALCULATION OF SYSTEM PARAMETERS

4.1 Flow Rate

When using electronic controllers, the flow rate needs to be set. The flow rate is the volume in ml divided by the duration in hours (mls per hour). This calculation can be expressed as a formula-

Flow rate = Volume (ml) / Time (hours)

4.2 Drop Rate

When using manual controllers, the drop rate needs to be set (drops per minute). This can be calculated using the following formula-

Infusion drop rate = Drop factor x Volume in ml / 60 x Time (in hours)

On some types of controller, the size of each drop of liquid is governed by the internal mechanics. It is fixed and cannot be altered. Typically, it is written on the machine. This invariable quality gives rise to the drop factor:

Drop factor = The number of drops it takes to make up one ml of saline fluid.

Two common sizes are:

For clear fluid : 20 drops per ml

for thicker substances, such as blood: 15 drops per ml

4.3 Calculation of the duration

We may need to calculate how long an infusion will last. Consider this example for clarification that calculate the duration of 100ml infusion of saline last if it is running at 42 drops per minute. Let us assume, the drop factor for the equipment is 20 drops per ml. we first need to find out how many millilitres are transfused per minute, we have to do this as follows:

The infusion drop rate is 42 drops per minute.

The infusion drop factor is 20 drops per ml.

If we divide 42 drops per minute by 20 drops per millilitre, we'll find out how many millilitres per minute.

42/20 = 2.1 ml per minute.

Now we can divide the overall infusion of 100ml by the milliliters transfused per minute to get the duration that is equal to 47.6 minutes.

5. RESULT AND DISCUSSIONS

Flow rate regulation is the control of the amount of medicine fed through our bloodstream. Without control technique, the rate of fluid administration relies on gravity alone. This can give the result in receiving either too much or too little fluid. The flow rate of medicine on the catheter tube is regulated either manually or by using an electronic controller. Regardless of how flow rate is regulated and nurses or patient's assistance must check on the tube regularly to ensure both rate of flow and delivery of the correct dosage. There are several reasons need to have fluids administered intravenously. For instance, some treatments rely on intravenous delivery such as rehydration after becoming dehydrated from illness or excessive activity, treatment of an infection using antibiotics, cancer treatment through chemotherapy drugs, management of pain using certain medications. The rate and quantity of intravenous solution has given depends on our medical condition, body size, and age. Regulation ensures the correct amount of fluid drips from a bag down the intravenous into your vein at the correct rate. Complications can give the result from receiving too much too quickly, or not enough too slowly. There are two ways to regulate the amount and rate of fluids given during intravenous therapy: manually and using an electronic controller arrangements. Both methods require to nurse to check regularly to be sure we are getting the correct amount of fluid. For manual method, the rate of fluid dripping from a bag into an IV can be regulated through a manual technique. Nurse increases or decreases the pressure that a clamp puts on catheter tube to either slow or speed the rate of flow. They can count the number of drops per minute to make sure the flow rate is correct and adjust it as needed. For electronic controller method, the rate of flow in the catheter can also be modulated with an electronic controller with motor arrangements. By using Arduino Uno controller is used to deliver the desired amount of fluid into the intravenous tube at the correct rate.

A few minor risks are associated with receiving of fluids intravenously. These include infection at the injection site, a dislodged intravenous catheter, or a collapsed vein. All of these are easily corrected or treated. We can avoid dislodging our intravenous catheter by being careful during fluid administration. A collapsed vein is more likely to occur if we need to have catheter tube in place for an extended period of time. Overload of fluid can cause symptoms such as a headache, high blood pressure, anxiety, and trouble breathing. Some overload can be tolerated if fairly health. But if we have other health problems, it can be dangerous. The symptoms of a low flow rate may vary depends on the person. The administration of intravenous fluids via intravenous infusion is common and very safe. In this regards, this system has been developed and tested. Experimental results are presented as follows. Figure 8. shows the variation of flow rate when the system is operated in DC Motor.

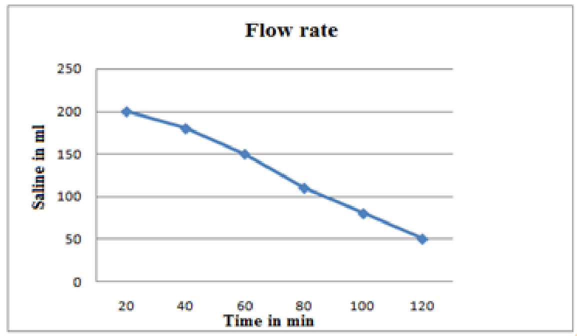

Fig.8 - Variation of Flow rate While using DC Motor

For our experimental study, considering 250ml of saline which is fed to human vein. At initial condition, based on the instructions by the controller, clamp with spring mechanism operates by the rotation of DC Motor. Due to this, intravenous tube open and flows the saline solution in to the vein. At t=20min, solution decreases from 250 ml to 200ml and every 20min the solution level is decreased. Threshold value is set by 50ml. At 120 min, saline solution is reached the threshold value. In this condition, Arduino controller is activated and give the signal to the motor. The clamp and spring mechanism is operated by the DC motor rotation, to clip the catheter tube to stop the saline solution automatically.

For improving the effectiveness of the system, a stepper motor with mechanical device arrangement is used to control the flow of saline. This is connected with the Arduino controller which is programmed to control the stepper motor and mechanical device to allow the saline drop by drop as per patient requirement. Figure.9 shows the variation of flow rate at different angle of rotation while using stepper motor. According to the instruction of the controller, the stepper motor is activated with an angle of 30°, 60° and 90°. Based on the patient's condition, angle of digression has been selected. For 30° deviation, saline starts to flow on the catheter tube and reduces from 250ml to 200ml at 20min and it reaches the threshold value which is set by 50ml at 140min. In the different angle of rotation like 60° and 90°, saline solution will be reduced for every 20min and reached the threshold value at 120 min and 100min respectively. When saline level reaches the threshold value, Arduino controller gives the signal to stepper motor which will activate the mechanical arrangement to close the catheter tube automatically.

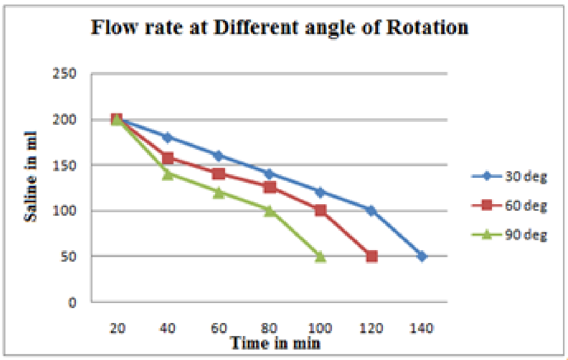

Fig. 9 - Variation of flow rate at different angle of rotation while using Stepper Motor .

6. LIMITATIONS

The final organizational objective provides a discussion on the limitations that exist within the system. The main concerns is that the system needs continuous power supply. If there is power cut in some situation there should be a backup for the system. If not, the system will not function. In the time of hardware failure the system should recognize and the awareness should be created accordingly. Some hospitals may not afford the price of the system. The backup of the data should be present.

7. CONCLUSION

Saline flow rate regulatory systems has been developed and effectiveness of these systems were tested with DC motor and Stepper motor. These proposed systems will reduce the manual effort. It requires very less human intervention as the system is completely automated. The system is very advantageous at night time since there will not be any need for continuous monitoring of saline level by humans. This system can be used in home as well, at an affordable cost because the automated system does not involve any recursive costing components. This system helps to reduce operational cost as well. Patients can be monitored in real time without the need for frequent visits by the doctor or nurses. Since the patients are monitored on continuous basis, the chances of reverse blood flow is controlled. From the observations of these two systems, the system with stepper motor is more efficient than the system with DC motor.

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